Tampa Bay Estuary Program
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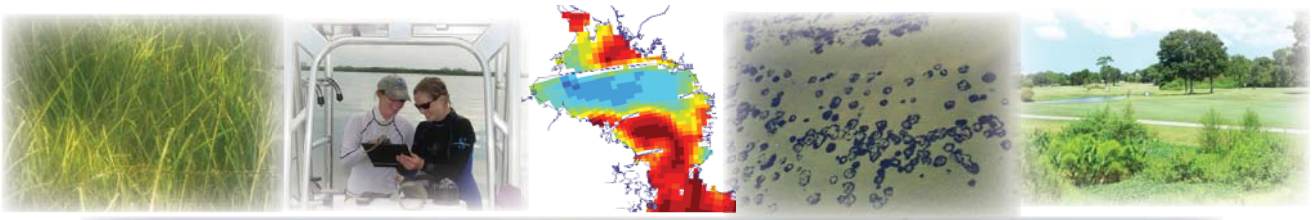
FEATHER SOUND SEAGRASS RECOVERY PROJECT:
Final Report and Management Recommendations for Feather Sound, Old Tampa Bay, Florida

FINAL REPORT

November 2007



Feather Sound Seagrass Recovery Project

Final Report and Management Recommendations for Feather Sound, Old Tampa Bay, Florida

Submitted to the Pinellas County Environmental Fund
by the Feather Sound Seagrass Recovery Project Team

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By the:
Feather Sound
Seagrass Recovery
Project Team

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Executive Summary

An aerial view of seagrass beds in the Feather Sound region of Old Tampa Bay. (Gandy Photography, Inc.)

The Feather Sound Seagrass Recovery Project was a multi-phase, multi-agency research project, funded by the Pinellas County Environmental Fund, to identify the potential causes of poor seagrass recovery in the Feather Sound region of Old Tampa Bay. Unlike many other areas in Tampa Bay that have experienced increases in seagrass acreage, seagrass coverage here, especially in the northwest quadrant of Old Tampa Bay, has been slower or declining. Until recent years, this bay segment also failed to meet one or both of its water clarity targets, prompting additional research.

During Phase 1 (2002-2003) the research team identified several potential causes of poor seagrass recovery, including poorer water quality than the other three quadrants sampled in Old Tampa Bay; slower circulation and flushing; epiphyte loading; and possibly hydrogen sulfide toxicity. These became the foundation for the second phase of the project.

Phase 2 (2004-2007) project tasks included:

- Developing and applying a seagrass prediction model;
- Seagrass sampling to support the model;
- Monitoring of volunteer patches of seagrass;
- Aerial photography and seagrass transect monitoring;
- Mapping the extent of effluent from wastewater treatment plants and septic systems;
- Calculating land-based nutrient loading; and
- Examining circulation effects on water quality.

Data and analysis were completed in 2006. An essential component of this project was development of management recommendations for the Feather Sound area. Results and management recommendations are discussed on the following pages. Complete technical reports are available on the accompanying CD.

Map of Florida and Tampa Bay. Feather Sound is noted in red in western Old Tampa Bay. (FWC, FWRI)

Executive Summary continued: Feather Sound is a "marginal" system

Scientific research projects, such as the Feather Sound seagrass recovery project, require extensive cooperation and collaboration by numerous individuals and agencies. During the Feather Sound projects, scientists and resource managers from local and state government agencies, private organizations, and universities collaborated to design and implement the project, collect and analyze data, finalize results, and develop management recommendations. The process was successful because the team members worked together to accomplish the shared goal of identifying the factors that are preventing seagrasses from recovering in Feather Sound and how they can be better managed.

Research projects and results can benefit greatly when they are reviewed by independent scientists not directly involved with the project. This can be especially useful when the reviewers are experts in a related subject matter. To strengthen the project results and recommendations, an external scientific peer review committee was convened to review the Feather Sound project results and management recommendations. The review committee had expertise in management of estuarine areas, seagrass ecology, and optical water quality modeling, among other areas.

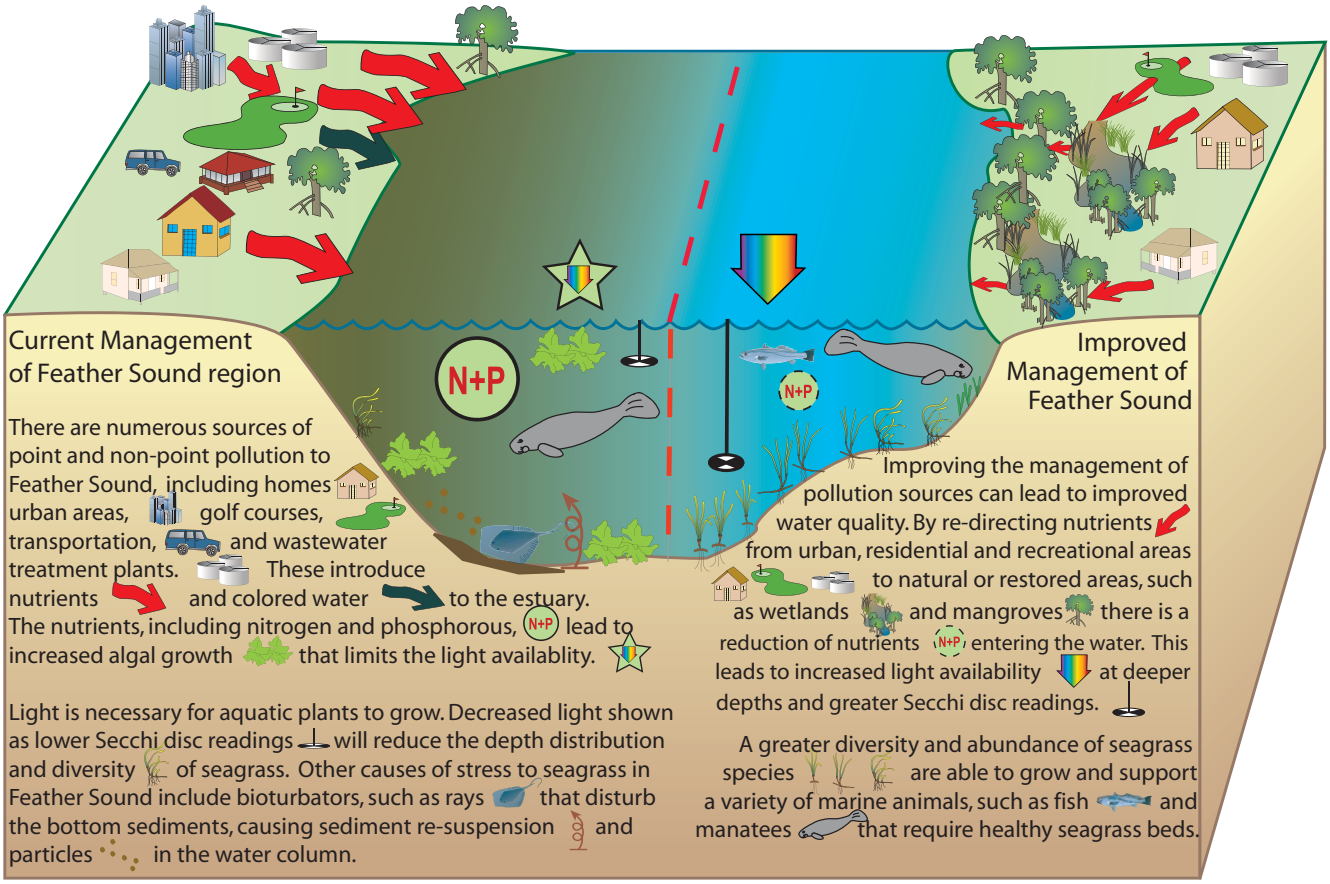
A Feather Sound workshop was held March 20th-21st, 2007 with the peer review committee, consisting of William Dennison and Walter Boynton (University of Maryland Center for Environmental Studies), Robert Virnstein (St. John's River Water Management District) and Charles Gallegos (Smithsonian Environmental Research Center).

The review committee found the project results to have a strong technical basis and agreed that the **Feather Sound region is a "marginal" system in terms of water quality and seagrass habitat that responds rapidly to improvements or degradations in water quality.** It supported the broad-based approach to improving management of the area and assisted with suggesting specific projects that may be most effective. The review committee also recommended future research priorities for the area, which are discussed later in the report.

The peer review team comments are included on the attached technical CD.

Feather Sound project team members discuss research results and recommendations with the peer review committee. (TBEP)

Executive Summary continued: Management recommendations



Base design and symbols courtesy of the Integration and Application Network.

Project Team recommends a variety of watershed improvements

It appears that there is no dominant factor controlling seagrass recovery in Feather Sound, rather a suite of non-optimal conditions that work synergistically to stress the system. The Project Team suggests that **improving the system will require a broad-based management approach for nutrients, sediments, pulsed freshwater inputs, and toxics.** The team also recommends maximizing the ability of mangroves and marshes to absorb nutrients from non-point sources that drain into western Old Tampa Bay.

Management recommendations:

- Improve management of urban and residential stormwater runoff
- Switch from septic systems to sewer
- Emphasize additional environmental planning and management for local golf courses
- Restore mosquito-ditched mangrove areas so that water drains more slowly into the bay and is able to be "polished"
- Implement stormwater projects at several locations around Lake Tarpon

Project team included many dedicated scientists

The project team members brought expertise and enthusiasm to the project. The following provides the name and affiliation of the principal team members by task.

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Feather Sound Seagrass Recovery Project Team

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Ray Pribble, *Janicki Environmental, Inc.*

Seagrass Monitoring to Support the Prediction Model (p. 15-16)

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Chris Anastasiou, *Florida Department of Environmental Protection, (formerly at Southwest Florida Water Management District)*

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Mark Flock & Cindy Meyer, *Pinellas County Department of Environmental Management*

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Feather Sound Seagrass Recovery Project Team

Project Management and Final Report Design

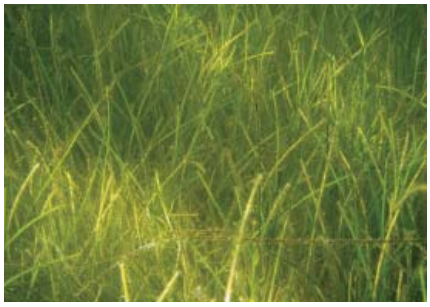
Lindsay Cross & Holly Greening, *Tampa Bay Estuary Program*

Seagrasses are important to Tampa Bay

Seagrasses are underwater plants that live in marine and estuarine areas. They typically colonize shallow waters, ranging from a few feet deep to more than 20 feet deep in areas with very clear water. The majority of seagrass beds in Tampa Bay are near the shoreline. Similar to terrestrial plants, they are rooted in the soil and require sunlight and nutrients to survive.

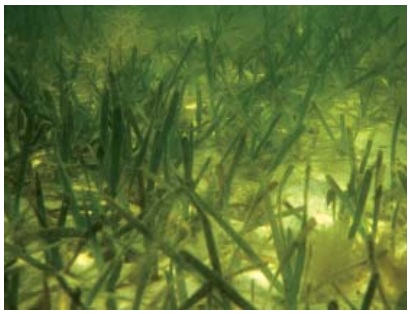
Seagrasses are used as habitat and as a food source by many Tampa Bay aquatic animals, such as fish, turtles, and manatees. They also help to filter the water, reduce erosion, and anchor the sediment on the bay bottom. These aquatic plants are an important part of the estuarine and marine ecosystem.

Seagrass coverage in Tampa Bay significantly declined between 1950 and 1980 due to increased pollution and alterations to the bay bottom, such as deepening areas for navigation channels or for land development. The following pages provide information about changes in seagrass coverage in Tampa Bay and the Feather Sound region.



Hw *Halodule wrightii* (Shoal grass)

One of the first species to colonize an area. In the Feather Sound region, it may be most susceptible to periodic poor water quality. When light availability is limited, shoal grass may die off. However, it can recolonize when water quality and light availability improve using underground rhizome (root) reserves or material from other areas. It is often used in transplant experiments because it grows rapidly.



Tt *Thalassia testudinum* (Turtle grass)

The heartiest seagrass species in Tampa Bay. It is more capable of withstanding short-term water quality problems, such as a year with high rainfall, because it has extensive rhizome reserves. However, if there are many years of poor water quality, turtle grass may die-off and may be more difficult to establish since it is very slow growing. It is rarely used as a transplant species.

Sf *Syringodium filiforme* (Manatee grass)

The least abundant of Tampa Bay's dominant seagrass species. It is more tolerant of poorer water quality periods than shoal grass, but not as resilient as turtle grass. It often grows in deeper areas, such as on the outer edges of sandbars, along with turtle grass. This species is able to recolonize quickly and re-fill donor material seagrass locations. It has been successfully transplanted in other regions of Tampa Bay.

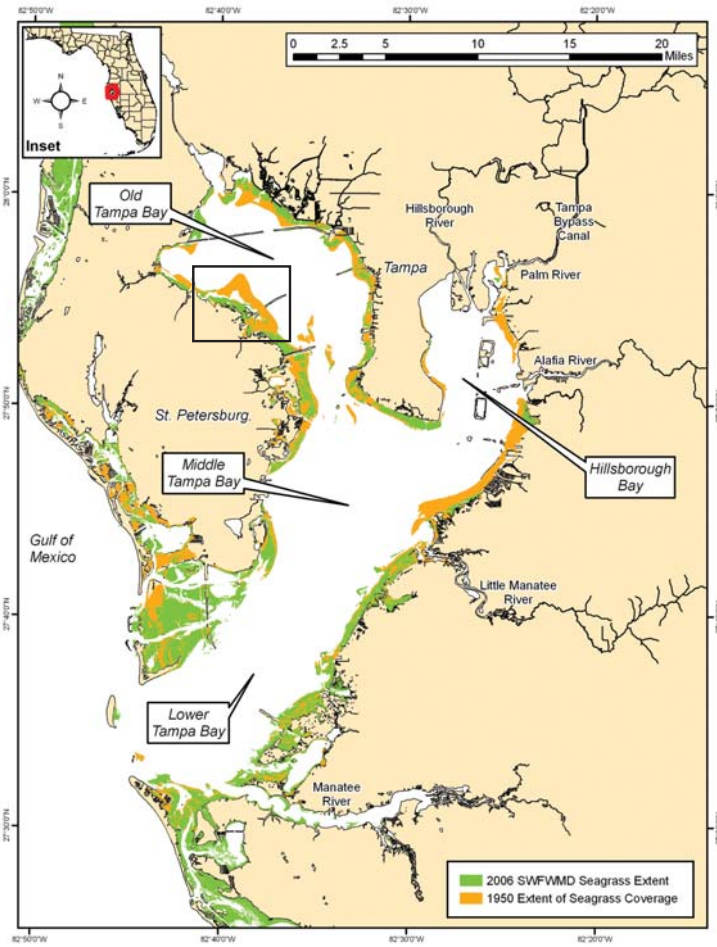
Seagrass coverage has changed in recent years

Aerial photographs show seagrass coverage

In order to track the seagrass acreage in Tampa Bay, the Southwest Florida Water Management District (SWFWMD) takes aerial photographs every other year. The photographs are analyzed for seagrass density and labeled as follows:

- Continuous seagrass (full, healthy beds),
- Patchy seagrass (sparse beds with bare spots), and
- No seagrass.

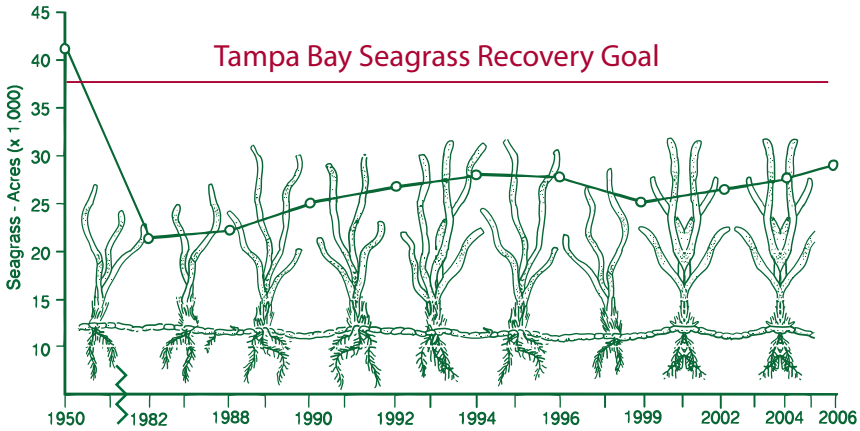
Scientists can compare the photographs and maps to determine where seagrass is recovering and where additional research or water quality improvements are needed.



Changes in Tampa Bay seagrass coverage from 1950 to 2006. The 2006 (green) coverage is overlaid on top of the 1950 (orange) benchmark coverage to show decreases. The large orange "hump" area shown in the box in Old Tampa Bay in the map above illustrates the loss of seagrass since 1950 in the Feather Sound region. (Data, SWFWMD; Map, EPCHC)

Baywide seagrass coverage

Seagrass coverage was nearly 42,000 acres in Tampa Bay in 1950 but decreased to almost half that by the early 1980s. In 2006, seagrass acreage was the highest recorded since the 1950s at 28,321 acres.



Tampa Bay seagrass acreage between 1950 and 2006 based on aerial photographs. (Data, SWFWMD; Graphic adapted from

Bottom Line: Seagrass acreage has increased in Tampa Bay, but continues to decline in Feather Sound.

Nutrient pollution limits seagrass growth

Healthy seagrass depends on good water clarity and sufficient light reaching the underwater grasses. Pollution from various sources can lead to poor water quality and clarity and decreases in seagrass. Some pollutants include chemicals and toxics, and other seemingly harmless substances can act as pollutants in large quantities.

Too much nitrogen can harm seagrass

Nitrogen is a nutrient that is necessary for plant growth. In appropriate quantities, it is beneficial to seagrasses. However, when there is too much nitrogen in the water, it can cause excessive growth of microscopic floating plants called phytoplankton. A common form of phytoplankton in Tampa Bay is algae. These tiny plants can cloud the water and decrease the amount of light that reaches the rooted seagrass plants.

Nitrogen can enter Tampa Bay through various forms, including natural sources, but also from human and animal wastes, fertilizer, and even emissions from factories and cars that fall onto the bay and the watershed as part of rainfall. Scientists and resource managers around Tampa Bay have set goals for reducing the amount of nitrogen that enters Tampa Bay as a way to improve water quality and clarity.

A large algal bloom in the Ybor Channel, near downtown Tampa. *(FWC, FWRI)*

Pollution control measures in Tampa Bay have increased seagrass acreage

Water quality in Tampa Bay has significantly improved since the 1980s due to wastewater treatment plant upgrades and improved management of point and non-point source pollution that contains nitrogen. Local, state and federal government agencies, along with private companies, have been working together to collectively reduce the amount of nitrogen that is delivered to the bay each year. Some examples of projects include upgrading power plants; improving irrigation of crops, such as strawberries, so that less fertilizer is needed; and updating stormwater systems so that runoff contains less nitrogen.

The reductions in nitrogen loading have led to better water quality and clarity and an increase in seagrass coverage in most parts of Tampa Bay.

Bottom Line: Reductions in nitrogen have resulted in seagrass increases in Tampa Bay.

Feather Sound 1 project produced useful findings

The Feather Sound 1 project was designed to assess the potential causes of poor seagrass recovery in the Feather Sound region of Old Tampa Bay. This project, which occurred from 2002-2003, consisted of eight major tasks. Complete results of this study are available in the document "Factors Influencing Seagrass Recovery in Feather Sound, Tampa Bay, Florida." The following two pages provide a brief summary of the major findings from the project and the "next steps" that became the foundation for the second project.

Feather Sound "hump" in 2003 with little to no seagrass coverage. (Gandy Photography, Inc.)

Scientist collecting a water sample. (SWFWMD)

Water quality poorer in Feather Sound

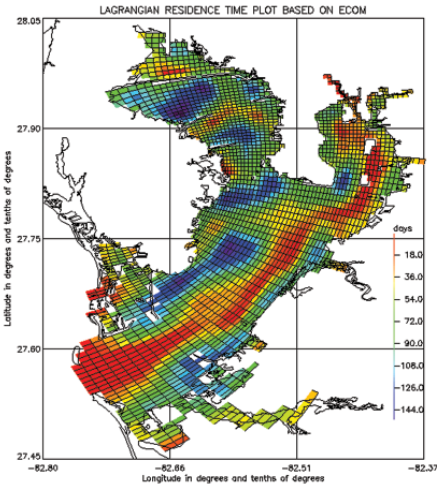
A major component of the first project was intensive water quality sampling. Scientists collected 700 samples and analyzed the water for parameters that measure light availability and factors affecting light penetration:

- Light attenuation (loss of light with depth),
- Transmittance (a measurement of the clarity of water),
- Chlorophyll *a* (an indicator of phytoplankton biomass),
- Turbidity (quantity of suspended matter), and
- Color (organic materials in the water).

The results indicated that water clarity in the Feather Sound (northwest) quadrant of Old Tampa Bay was poorer than in the other three quadrants. Reduced water clarity may be the primary factor in poor seagrass recovery, but not the only factor.

Circulation slower in Feather Sound

Computer models can predict circulation patterns and water movement. An earlier model output suggested that circulation was slower in the Feather Sound region than in other areas of Tampa Bay. The map below shows residence time near Feather Sound up to 144 days (shown in dark blue), compared to less than a week in other areas (shown in red). This decreased flushing may lead to poorer water quality, especially if the water contains excessive nutrients or pollution. Additional modeling was performed in the second study.



Residence time in Tampa Bay. Shorter residences times are shown in warmer colors; longer in cooler colors. (USF Marine Science)

Scientists observed seagrass from air and water

Seagrass monitoring shows continued declines in Feather Sound

Seagrasses within the four quadrants were monitored for changes using aerial photography and seagrass-intensive monitoring. Scientists sampled 41 sites throughout Old Tampa Bay, plus a fixed transect within each quadrant. At each location they recorded the presence of seagrass, abundance, height of blades, and the density along the transect. These results were compared to the transect results from previous years to look at large- and small-scale changes.

Overall, there was significant shoal grass loss in the Feather Sound quadrant between 2002 and 2003, with generally stable beds in the other three quadrants.

Patches of shoal grass with "donut" formations. *(Gandy Photography, Inc.)*

Volunteer seagrass patches develop "donut" formations

Patches of shoal grass that became established during 2001 and 2002 began to die off in late 2002, leaving bare patches in the middle. Scientists began investigating why these "donut" formations occurred and continued the research, focusing on five possible causes, in the second project.

Scientist measuring blade lengths of seagrass. *(COTBSG)*

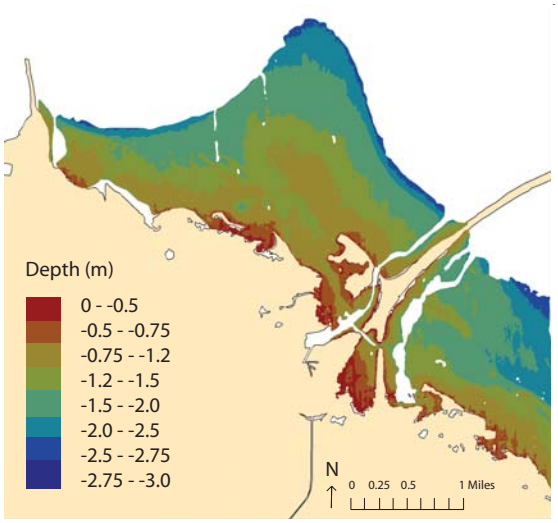
Epiphytes coat seagrass blades and reduce light availability

Epiphytes are plants and animals that live on the surface of another plant and can reduce the amount of light that reaches the seagrass blades. They are observed on seagrass in Tampa Bay and other areas. Epiphytes may be especially abundant during periods of poorer water quality and may transition from plant-like epiphytes that require light to particle-filtering animals. During the first project, epiphytes caused about 25-32% light reduction in all portions of Old Tampa Bay. Light reduction by epiphytes was highest in 2003 in the Feather Sound region.

Epiphytes on manatee seagrass blades. *(FWC, FWRI)*

Feather Sound 2 project continued exploration

The first Feather Sound project provided useful information about the study area and helped scientists learn more about some potential causes of poor seagrass recovery. Following the conclusion of the project, scientists agreed that there were still additional aspects to explore. Those factors, discussed on the previous pages, plus other ideas, became the basis for the Feather Sound 2 project. The project hypotheses are described below.



A scientist (above left) takes measurements of elevation in Tampa Bay. Results can be graphed by a computer program (above right) to show the overall patterns of elevation in a given study area. Water depth is an important factor in seagrass survival because there is generally less light available at deeper depths, especially when water clarity is marginal or poor. Elevations can also change over time due to a number of factors, including erosion or accumulation of sediments. (COTBSG, PCDEM)

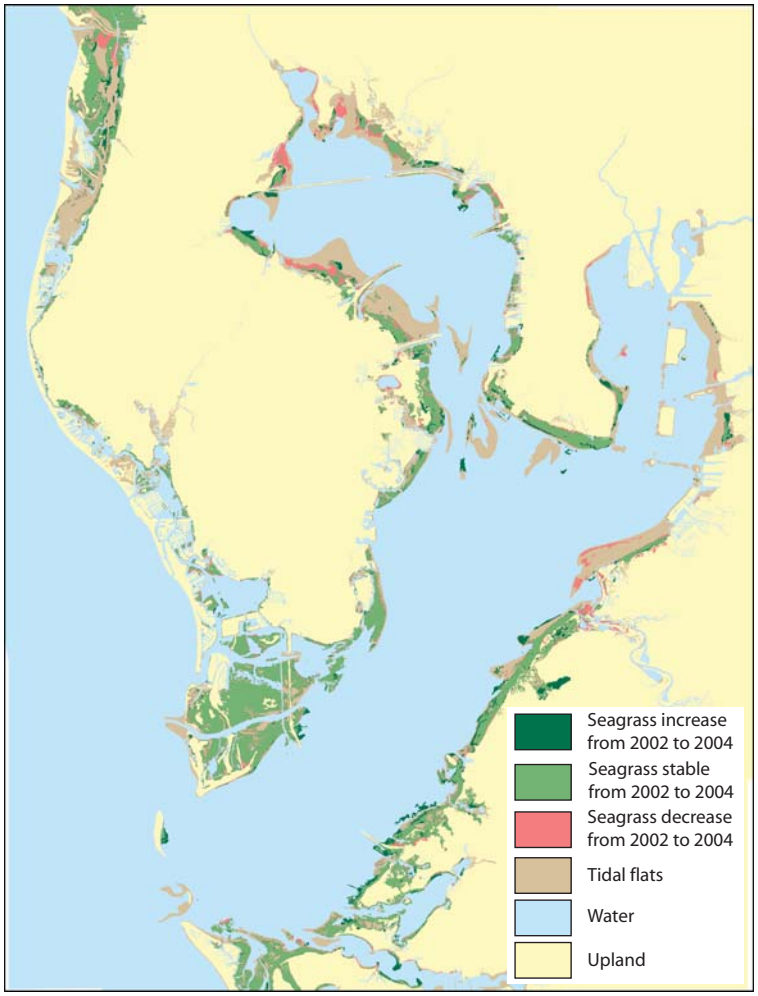
Hypotheses tested during the Feather Sound 2 project

- Water quality is poorer in Feather Sound, leading to decreases in seagrass.
- Seagrasses in Feather Sound respond differently to available light than in the other three quadrants of Old Tampa Bay.
- Slower circulation in Tampa Bay may be linked to poorer water quality.
- Altering the Howard Frankland Bridge causeway may improve circulation in western Old Tampa Bay.
- Seagrass "donuts" may be caused by several factors, including clonal senescence, nutrient depletion, lack of oxygen, sulfide toxicity, or bioturbation.
- While there have been recent gains in seagrass acreage in other portions of Old Tampa Bay, seagrass coverage continues to decline in Feather Sound.
- New techniques may identify sources of anthropogenic nutrient pollution.
- Stormwater runoff may be a significant source of nutrients to Feather Sound.

Model developed to predict seagrass growth

A primary component of the Feather Sound 2 project was development, testing, and modification of a model to predict the occurrence and distribution of seagrass based on light availability and depth of the area. This model was important because results from the first study suggested that poorer water quality in the Feather Sound quadrant may be a primary factor in slower seagrass recovery, although scientists did not think this was the only cause. If an area has suitable water quality but is not able to support seagrass, there may be other factors that are limiting seagrass growth.

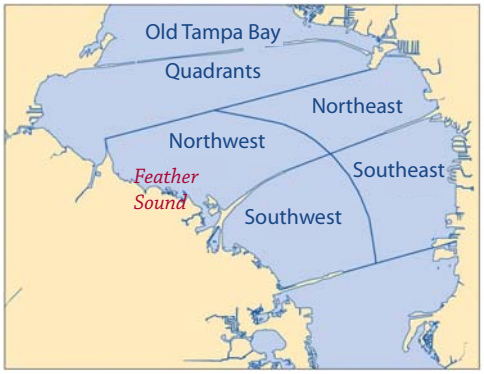
The model used extensive water quality data collected during the first study, plus other available data, to answer questions about seagrass occurrence in Old Tampa Bay.



Difference in Tampa Bay seagrass coverage using aerial photographs between 2004 and the previous mapping effort in 2002. The majority of seagrass declines (pink) occurred in Old Tampa Bay. (SWFWMD)

The prediction model includes these data sources:

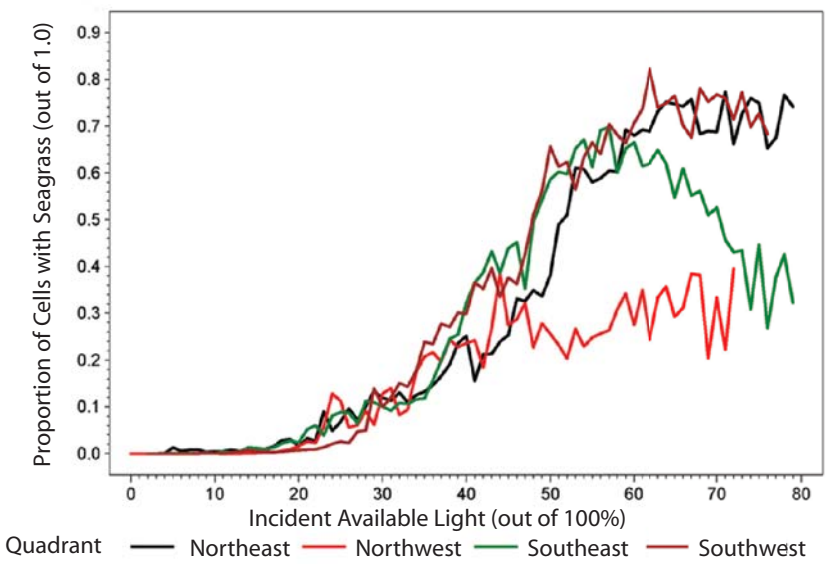
- Water quality data from Feather Sound 1 project (2002-2003),
- Water quality data from deeper water sites collected by the Environmental Protection Commission of Hillsborough County (EPCHC) (1988-2004),
- Seagrass coverage data from SWFWMD based on aerial photography (1988, 1990, 1992, 1994, 1996, 1999, 2001, and 2004) and the Feather Sound 1 project.
- Bathymetry (water depth) data from the National Oceanographic and Atmospheric Administration (NOAA) and the U.S. Geological Survey (USGS).



Old Tampa Bay was divided into four quadrants and overlaid with a 50m x 50m grid. Feather Sound is in the northwest quadrant. (JEI)

Seagrass presence affected by available light

Prior to using the model to predict where seagrass should grow, scientists examined whether there was a relationship between incident available light (light availability) and seagrass presence/absence. Each grid cell was labeled as having seagrass coverage at some time between 1988-2004 or not having seagrass, based on SWFWMD data collected every two years. This information was then compared to the amount of light available to seagrass (based on water quality and depth). The relationships were graphed to show the proportion of cells with seagrass (the vertical axis) within a quadrant and the percent incident available light (horizontal axis). The graph below depicts the relationships in the four Old Tampa Bay quadrants.



Proportion of cells with seagrass as a function of percentage incident light available, based on EPCHC water quality data. *(JEI)*

The relationship between available light and seagrass presence appears to be different in the NW quadrant where Feather Sound is located than in the other three quadrants. While the proportion of areas with seagrass increases in other quadrants with increased light, the NW quadrant cells appear to be limited to about 45% incident available light, suggesting seagrass in this area may respond differently to light availability.

Application of the seagrass prediction model

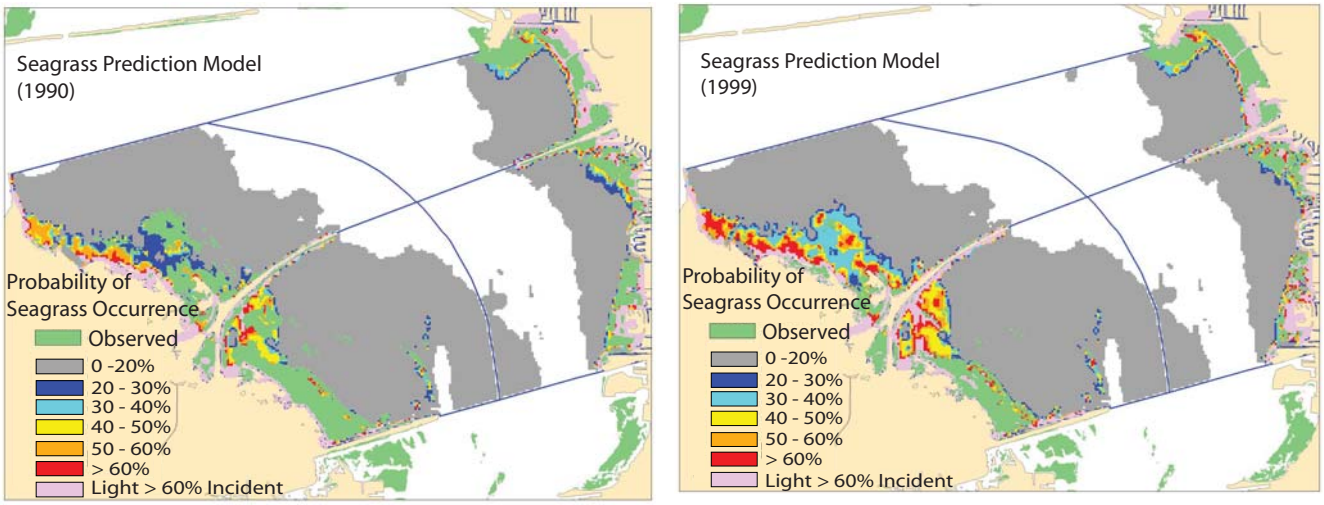
Based on the results shown in the graph above, scientists hypothesized that seagrass may respond differently to light availability in the NW quadrant than in the other three. The pattern of depth distribution as a function of available light is more similar in the other quadrants. Therefore, the seagrass prediction model utilized the relationship between available light and seagrass presence from the other three quadrants (excluding the NW quadrant) to predict, based on depth and water clarity, the probability of seagrass occurrence in the NW quadrant. The model outputs are given for the entire Old Tampa Bay study area and the hypothesis was that the model would more accurately predict the occurrence of seagrass in the other three quadrants that follow a similar relationship with available light. The purpose was to determine where water quality might not be the limiting role in seagrass recovery.

The model was refined several times throughout the project by utilizing additional data and validating the model results with in-field seagrass monitoring.

Bottom Line: Seagrass in the northwest quadrant reacts differently to light than seagrass in the other three Old Tampa Bay quadrants.

Model better predictor in other three quadrants

The seagrass prediction model was run for each year seagrass distribution data were available. Scientists were then able to compare the model predictions to what was actually observed in aerial photographs. The results varied both by year and by quadrant. The examples below utilize the results from the original model output using SWFWMD seagrass coverage data and EPCHC water quality data taken from deep water sites.



Model outputs from 1990 (left) and 1999 (right). The probability of seagrass occurrence is overlaid with observed seagrass coverage results (green). Other colors indicate where the model predicts seagrass should occur but where it was not observed. The model under predicted seagrass presence for 1990. There was a significant amount of observed seagrass coverage in the western quadrants, especially Feather Sound, in areas where the model predicted lower probability of seagrass coverage. Conversely, the model over predicted seagrass for 1999. Near the Feather Sound hump area, the model predicted seagrass occurrence at greater than 30%, shown in light blue, yellow, orange, and red. Had seagrass been observed, these areas would be covered with a green signature. In the other three quadrants, the observed and predicted coverages are more similar. (JEI)

Model results demonstrate that predictions (compared to observations) were better for the other three quadrants than in the NW quadrant. Because the model was developed using data from those three quadrants, these results were expected. In the NW quadrant, predictions sometimes show relatively low probabilities of occurrence (30% or less) in the Feather Sound area when seagrasses were observed [1988, 1990 (shown), and 2004], and sometimes show relatively high probabilities of occurrence (more than 30%) in areas where seagrasses were not observed [1994, 1996, and 1999 (shown)].

The differences can be interpreted two ways:

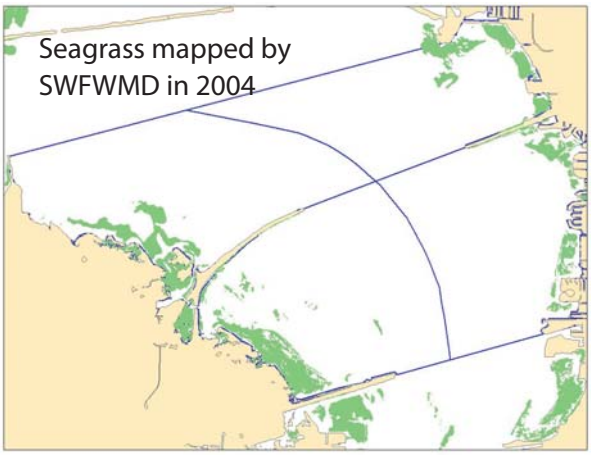
- This is a real phenomenon: seagrass in the northwest quadrant do react differently to light than in the other three quadrants, or
- The data and/or the relationship between water quality and seagrass used in the model are not the most appropriate for predicting seagrass in this area.

The following page provides a discussion of the data sources used to develop the model and explains modifications that helped to improve the model success.

Bottom Line: The model, as originally configured, over- or under-predicted seagrass occurrence in the northwest quadrant for several time periods.

Shallow water data improves model predictions

Scientists suggested that the model may be more accurate in predicting seagrass presence or absence using water quality data from shallower areas where seagrass typically grows, rather than in deeper water (EPCHC sites) that may not support seagrass. Scientists had collected extensive water quality data during the first Feather Sound project (2002-2003) in shallower locations. These data were used in the model along with 2004 seagrass coverage and compared to the model results with deep water data. The 2004 results are shown below.

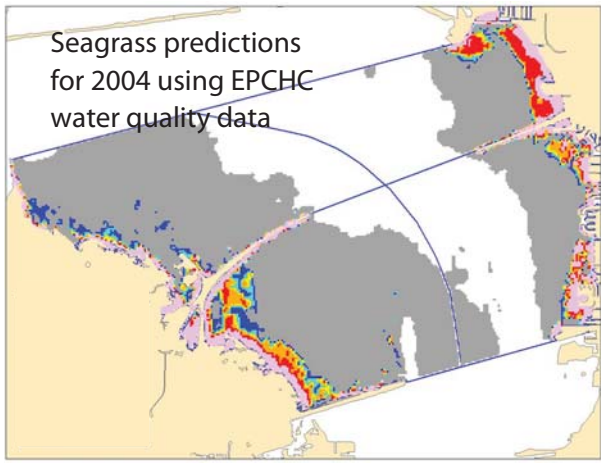


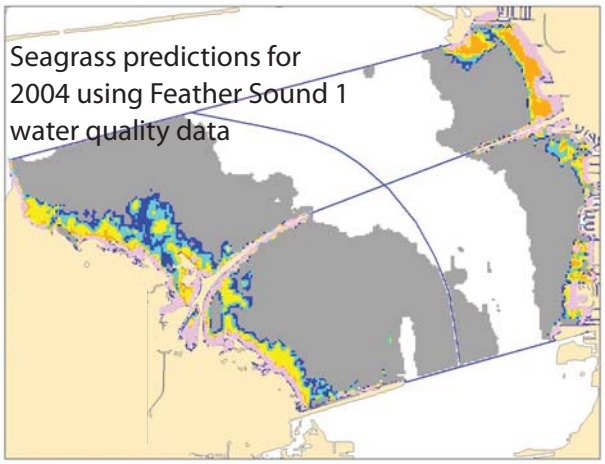
Model outputs utilizing 2004 SWFWMD seagrass distribution and water quality data from two sources. The left graphic depicts where SWFWMD mapped seagrass in 2004. The lower left graphic is the model output showing where seagrass was predicted to occur in 2004 using water quality collected from EPCHC deeper-water sites. The lower right graphic uses water quality data collected during the Feather Sound 1 study. Many of these sample locations were located in shallower water where seagrass may be more likely to grow.

Seagrass presence is defined as a 20% or greater probability of occurrence. Gray areas indicate zero to very low probability of occurrence. Much of this area is too deep to support seagrass due to limited light penetration. Areas with >60% incident light (pink) may be exposed at low tide and are not suitable for seagrass. Areas in white were not included in the model. (JEI)

Probability of Seagrass Occurrence

0 - 20% | 20 - 30% | 30 - 40% | 40 - 50% | 50 - 60% | > 60% | Light > 60% Incident





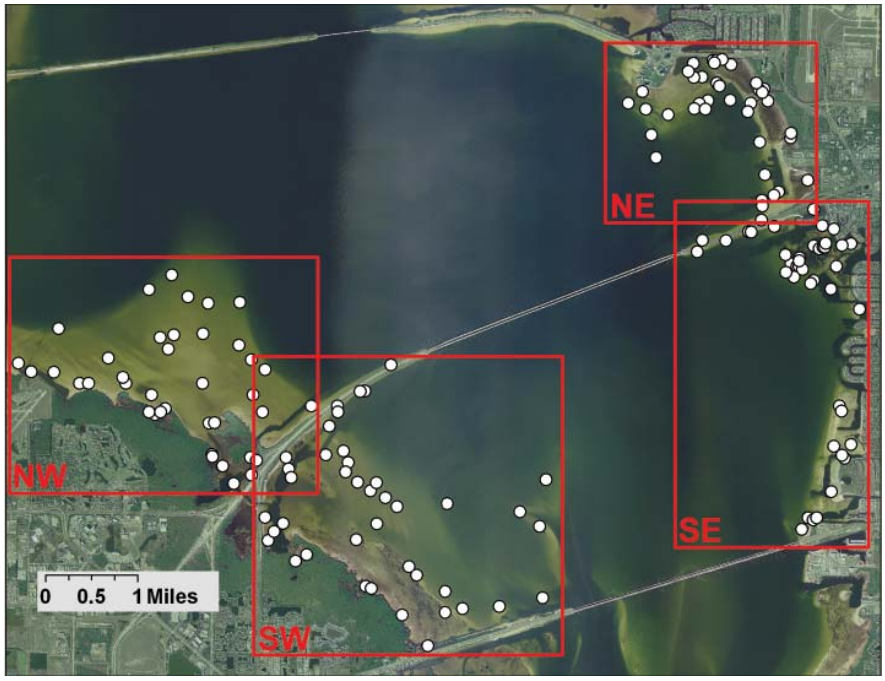
Data used in the model affected the predicted probability of seagrass occurrence, shown by different results for the EPCHC and the Feather Sound 1 model outputs. An additional version of the model (which is not shown) used inputs from a Gallegos optical model that predicted light attenuation in areas that were too shallow to be sampled.

The model best predicted seagrass probability in NW and NE quadrants using water quality data from the first Feather Sound project. It correctly predicted seagrass in the NW quadrant in cells where seagrass existed 84% of the time. In the SE and SW quadrants, estimated water quality using the Gallegos optical model provided the best results. Additional sampling in shallower areas may be useful for seagrass prediction models in the future.

Bottom Line: Model gave better predictions using shallow water quality data.

Scientists snorkel to find seagrass

Scientists used the outputs from the seagrass prediction model and field observations of seagrass presence/absence to verify the model's accuracy by viewing seagrass in the field. The sampling effort included 160 sampling locations: 40 samples in each of the four geographic quadrants of the study area. In order to develop a systematic way to verify the model predictions, results were divided into four categories with 10 sites monitored per category.



160 field observation sample locations within the four quadrants. *(FWC, FWRI)*

- Category 1: Regions of Old Tampa Bay that were NOT mapped as seagrass in 2004 by SWFWMD, but where the model predicts a HIGH probability of seagrass.
- Category 2: Regions of Old Tampa Bay that WERE mapped as seagrass in 2004 by SWFWMD, but where the model predicts LOW PROBABILITY of seagrass.
- Category 3: Regions of Old Tampa Bay that WERE mapped as seagrass in 2004 by SWFWMD, but where bathymetry data report DEPTH < 0 feet at mean water (water depth should be too shallow to support seagrass growth since seagrass would be exposed at low tide).
- Category 4: Regions of Old Tampa Bay that WERE NOT mapped as seagrass in 2004 by SWFWMD, but where the water depth should support seagrass growth (bathymetry data report between 4 and 5 1/2 feet at mean water).

Scientists recorded the following during sampling:

- Seagrass and algae presence/absence and density,
- Sediment type (sand, mud, hard bottom, etc.),
- Water quality parameters (water depth, temperature, pH, dissolved oxygen, and water clarity variables).

When applicable, scientists noted other factors that may influence seagrass presence/absence, such as high wave energy, seawalls, channels, or high levels of algae or epiphytes (that may limit light availability for seagrass).

Scientist collecting water quality data at a site near Feather Sound. *(TBEP)*

Predictions improve with measured field depths

Scientists sampled 160 locations in Old Tampa Bay, recording data about seagrass presence/absence, along with other information. In order to avoid bias, scientists did not know during sampling whether a site was predicted to have seagrass or not. Their results were then compared to results from the seagrass prediction model to determine the model's accuracy.

Scientists snorkeled to determine seagrass presence/absence within 1 meter x 1 meter quadrants (left), and recorded other site information (right) near Feather Sound. (TBEP)

Depths used in model often incorrect

One of the most common findings during monitoring was the difference in depths used in the seagrass prediction model and those measured in the field, corrected for tide. At the beginning of model development, NOAA/USGS bathymetry data were compared to precise elevation measurements at certain locations. While there were slight differences, it was concluded that the bathymetry layer was sufficient. However, field monitoring suggests that differences may be significant in some areas. Scientists dove to depths of more than 15 feet at some sites, while others were located on land, neither supporting seagrass.

To remedy this, the seagrass prediction model was re-run using depths measured in the field. The graphics on the right show results of comparison of observations and model predictions using original and corrected depths.

Model Predicted	Observed in field: YES	Observed in field: NO
YES	59 (54%)	51 (46%)
NO	31 (62%)	19 (38%)

Comparison of seagrass observations and model predictions using original depths.

Model Predicted	Observed in field: YES	Observed in field: NO
YES	49 (74%)	17 (26%)
NO	41 (44%)	53 (56%)

Comparison of seagrass observations and model predictions using measured depths from sampling.

The original seagrass prediction model correctly predicted either seagrass presence or absence when compared to field observations in 49% of cells (78 out of 160). When the model was re-run using depths measured in the field, the model had an improved prediction rate of 64% overall (102 out of 160). Updating the bathymetry layer and including water quality sampling from shallow areas in the model may improve its effectiveness.

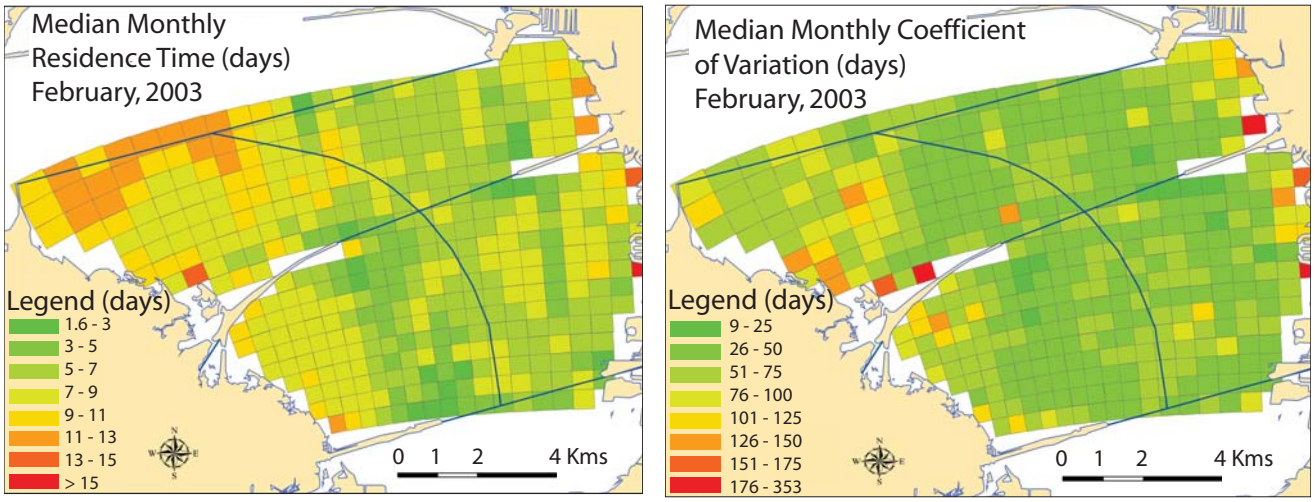
Bottom Line: Revised model using depths recorded in the field improved prediction of seagrass occurrence or absence to 64%.

Circulation model describes water movement

Scientists were intrigued by the circulation modeling results from the first Feather Sound project that suggested that flushing rates were slower in the Feather Sound region. They applied a hydrodynamic model to examine how slower circulation (increased residence time) may impact localized water quality. The hypothesis was that longer residence time (the period of time that a water mass spends in a given area) may be associated with poorer water quality. For example, if pollution was discharged into an area with longer residence time, it may have a greater opportunity to negatively affect water quality and, possibly, seagrasses. If the water had high amounts of nutrients that can cause algal blooms, the water could become cloudier and block sunlight needed by seagrass.

Scientists started by calculating median residence times and coefficients of variation for the study area by month during 2002-2003 in each model cell. The median number is the middle value in a set of numbers. The coefficient of variation (CV) is a comparison of the amount of variation between data sets. In this model, a larger CV indicates that there is more variation in the individual median monthly residence time values.

In the model outputs shown below, there are longer median residence times in the NW quadrant, as well as greater CVs. This suggests that, although water exchange in areas of the NW quadrant is typically slower compared to other areas in Old Tampa Bay and the rest of the bay, episodic (short-term) events may result in a rapid exchange of water, causing a larger median CV value. This rapid flushing of water may improve conditions for seagrass growth.



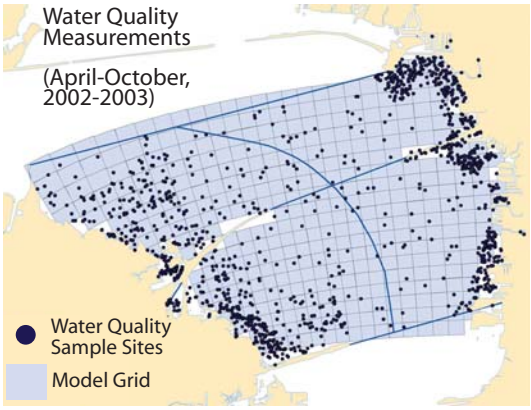
Median residence times and coefficients of variation in Old Tampa Bay for February 2003. The Feather Sound region of Old Tampa Bay, especially north of Big Island, had a higher residence time and higher coefficient of variation (shown in orange and red) than in other modeled areas of Old Tampa Bay (shown in yellow and green shades). This indicates that circulation is slower in this area, and may also be more susceptible to short-term events, such as storms, that can quickly flush water from the area. (JEI)

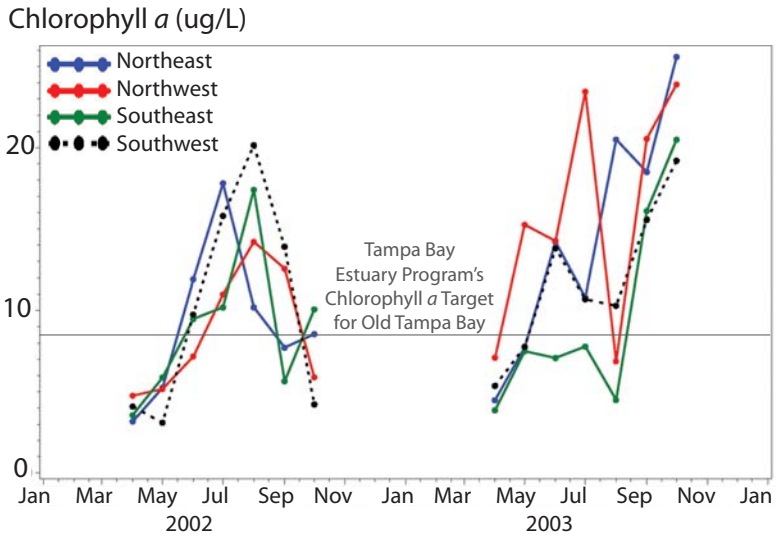
Bottom Line: Feather Sound is a "flashy" area. While residence time is usually longer than in other parts of Old Tampa Bay, it can change rapidly, especially after large rain events.

Relationship between circulation and water quality not consistent over study period

During the first Feather Sound project, scientists collected intensive water quality data throughout the four Old Tampa Bay study quadrants (shown below right). Data included concentrations of three factors that can limit light penetration in the water column: chlorophyll *a*, color, and turbidity. Scientists hypothesized that longer residence times and poorer water quality may be working synergistically to prevent seagrass growth.

In order to test the hypothesis that circulation may affect water quality, scientists compared residence time and CV model results to water quality data collected during the first project to determine if there were any relationships. Specifically, scientists examined the relationship between median residence time (discussed on the previous page) and median chlorophyll *a* concentrations during each year of sampling from the first project.





Location of water quality sample sites from Feather Sound the 1 project collected between April-October 2002 and 2003 (above).

Average chlorophyll a values (an indicator of algae concentration) in Old Tampa Bay during April-October 2002 and 2003. Scientists have set a chlorophyll a target for this bay segment at 8.5 micrograms per liter (ug/L). Higher values indicate more algae in the water, which can decrease the amount of sunlight that reaches seagrass. Values were highest in the northwest quadrant in 2003, indicating that water quality may have been poorer in this quadrant during the 2003 study period. However, water quality for three constituents (chlorophyll a, color, and turbidity) was not the worst in the northwest quadrant during the earlier 2002 study period. (JEI)

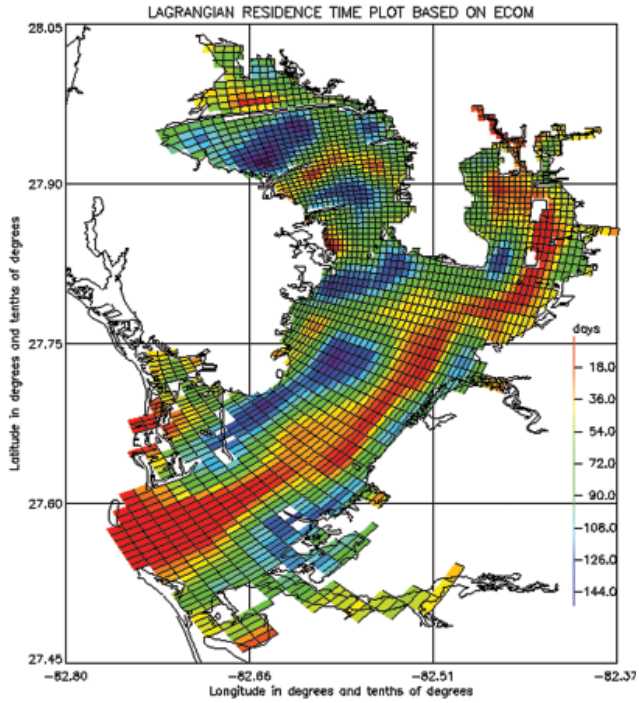
Relationship was not consistent between water quality and residence time for 2002 and 2003

The NW quadrant had poorer water quality (higher median chlorophyll *a*, color, and turbidity) than the other three quadrants when averaged over the April-October data periods in 2002 and 2003. However, there was no consistent pattern of lower water quality within any of the quadrants as compared to the other three quadrants. Variability was also similar across segments and years. Overall, there was no difference in water quality between the four quadrants that could be associated with the modeled residence times.

Bottom Line: Longer residence times near Feather Sound could not be linked with poorer water quality using a circulation model.

Models can simulate circulation scenarios

Results from a circulation model that was used during the first Feather Sound project suggested that residence time was much longer in this part of Tampa Bay than in other areas. An additional application of the model that was discussed on the previous page examined the relationship between the circulation model and water quality data. Scientists hypothesized that the creation of the Howard Frankland Bridge causeway may be blocking water movement on the west side of Old Tampa Bay. It is possible that a hole or culvert cut through part of the causeway may increase circulation in the Feather Sound area. Scientists also wondered how circulation would change if the western portion of the causeway was completely removed.



An earlier version of a Tampa Bay circulation model. Results suggest that circulation near Feather Sound (shown in blue) is slower than in other parts of the bay. (USF Marine Science)

In order to test the theory that the causeway may be impeding water movement near Feather Sound, scientists modified the circulation model for the following scenarios:

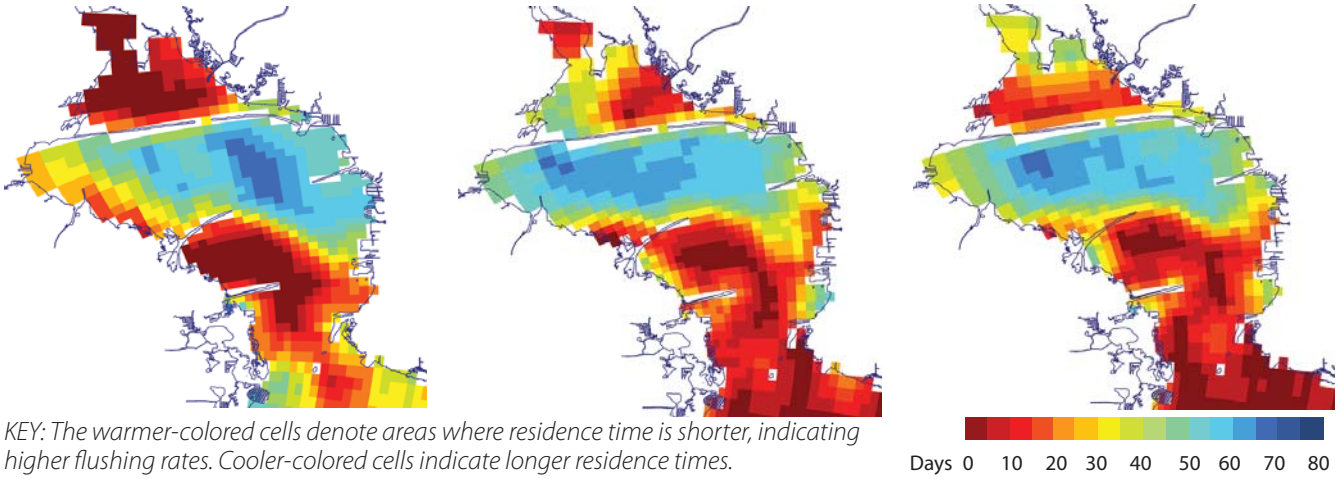
- Current configuration of the Howard Frankland Bridge causeway,
- A cut-through (or culvert) in the western section of the causeway, or
- Complete removal of the western section of the causeway.

Western side of the Howard Frankland Bridge causeway, constructed in 1959, in the Feather Sound region. (USGS)

Three scenarios involving modification of the Howard Frankland Bridge causeway used in the USF circulation model. White model cells indicate upland areas, such as the causeway, while colored cells indicate submerged areas. On the left is the current bathymetry showing the complete causeway. The middle scenario includes a cut through the center of the causeway, shown by an additional colored cell. The scenario at the right shows complete removal of the western causeway shown with no white cells along the causeway. (USF Marine Science)

Engineering fixes may only move the problem

A version of the baywide circulation model was run for only Old Tampa Bay, assuming moderate rainfall conditions, and using the three causeway configuration scenarios. Modeling results, shown below, demonstrate that putting a hole in or completely removing the western portion of the causeway may not significantly improve water circulation in Feather Sound. While the residence time would slightly decrease, this alteration may negatively affect other portions of Old Tampa Bay. From this limited set of scenarios, it appears that changing the flow patterns near the Howard Frankland Bridge causeway may actually increase residence time in the northern portion of the Old Tampa Bay above the Courtney Campbell causeway (north of the Howard Frankland Bridge causeway) and in the region southwest side of the Howard Frankland Bridge.



KEY: The warmer-colored cells denote areas where residence time is shorter, indicating higher flushing rates. Cooler-colored cells indicate longer residence times.

The graphic on the left shows circulation in Old Tampa Bay without any modifications to the Howard Frankland Bridge causeway. The middle graphic shows circulation with a hole through the causeway; circulation would improve near Feather Sound, but may be slower south of the causeway and in the upper portion of Old Tampa Bay. Removing the western causeway (right graphic) would also increase residence time south of the existing causeway and in northern Old Tampa Bay. *(USF Marine Science)*

Results from this circulation modeling appear different than those from the first Feather Sound project (pages 8 and 19) that suggested very long residence times near Feather Sound. Although a version of the same circulation model was used, results can vary depending on many factors, such as time period modeled, the amount of rainfall used in the calculations, and the area examined.

Modeling of alternative causeway scenarios suggest that putting a hole through or removing the western portion of the causeway may cause some changes in circulation, but scientists agreed that using an engineering fix may not be the best option for improving water quality at Feather Sound at this time.

Scientists and modelers will continue looking at various options for recovering seagrass in Feather Sound. Designing and applying models, such as the circulation model above, are useful for predicting how the environment may respond to different management scenarios and will continue to be used in Tampa Bay.

Bottom Line: Altering the Howard Frankland Bridge causeway may not be beneficial to overall water quality in Old Tampa Bay.

Monitoring tells a story of seagrass health

Scientists return to areas over many years to aid understanding

Long-term monitoring of seagrass helps scientists learn about seagrass health and the best ways to manage areas in Tampa Bay. In this study, scientists used three techniques for monitoring that were also performed in the first project. These included:

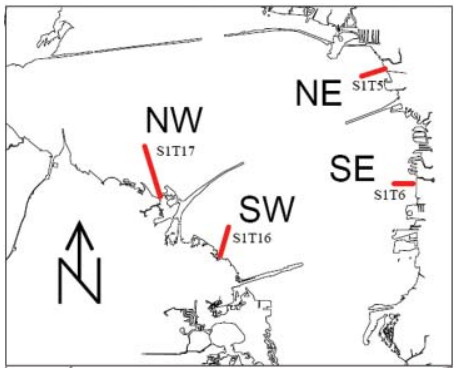
- Seagrass transect monitoring,
- Aerial photography, and
- Elevation measurements.

By combining information over many years, scientists can look at how seagrass in an area has changed.

Seagrass Transects

Transect lines provide a way to monitor seagrass over time within a study area. Transect monitoring began in Hillsborough Bay in eastern Tampa Bay in 1997, in Old Tampa Bay in 1998, and in Feather Sound in 2001.

In Old Tampa Bay, there are 12 permanent transect lines. For this study area, scientists collected data at four transects, one in each quadrant (shown above right). Scientists return to these transects year after year and record seagrass data.



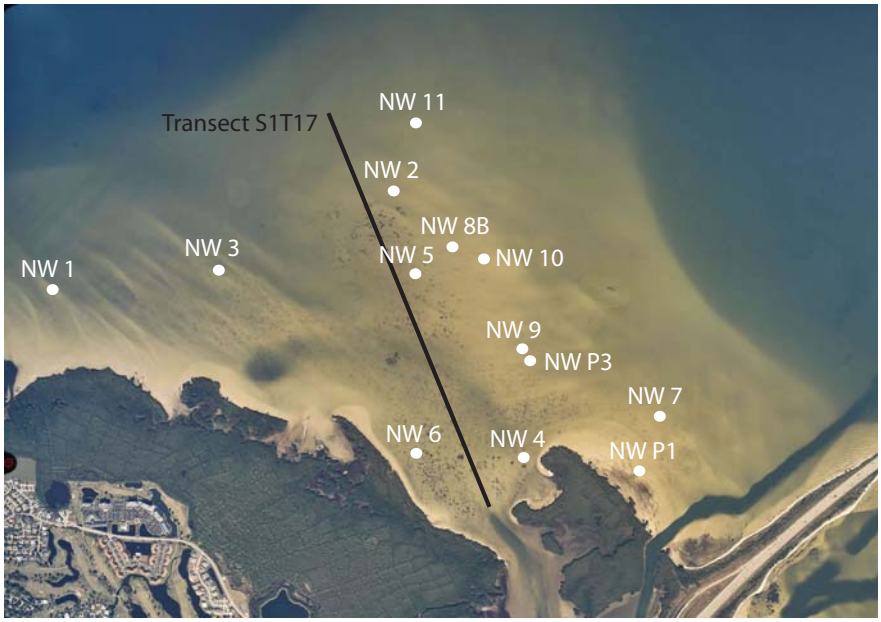
Four seagrass transects in the study area of Old Tampa Bay quadrant. (COTBSG)

Information collected along transects included:

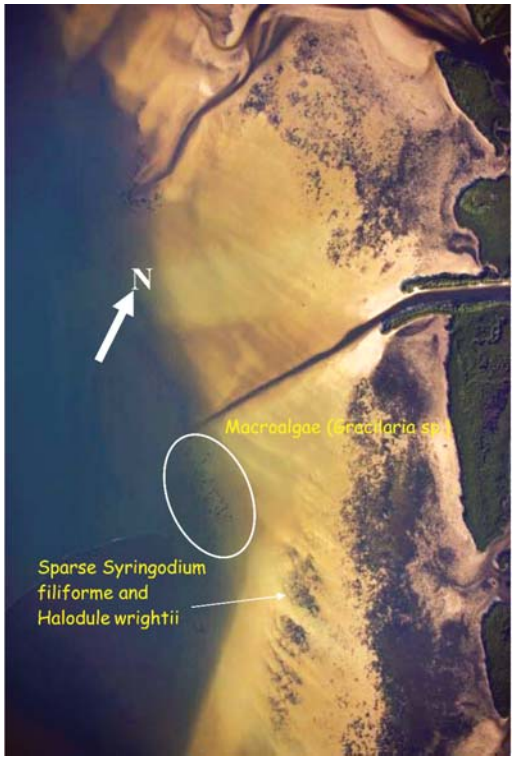
- Seagrass species (the type of seagrass present),
- Abundance (out of 100% cover),
- Blade length, and
- Short-shoot density (the number of short shoots per unit area, usually in square meters).

Scientists can put together a picture of the seagrass in an area and the health of the system using information gathered during transect monitoring. For example, scientists can determine whether the seagrass species have changed; whether new seagrass has colonized an area; or whether faster-growing, transitional species are being replaced with slower-growing, more persistent species. Scientists can use this information to determine if an area is improving or if it needs to be managed differently to encourage seagrass growth.

Fixed seagrass transect in the Northwest quadrant, plus the 13 locations used for measuring seagrass characteristics and elevation. (COTBSG)



Aerial photographs support transect data



Macroalgae and seagrass in northeastern Old Tampa Bay. (Gandy Photography, Inc.)

Aerial photography shows "big picture"

On-the-ground information from transect monitoring provides small-scale and in-depth information about a specific area. However, aerial photographs can show large-scale changes and the "bigger picture."

During the project, aerial photographs were taken twice a year in Old Tampa Bay. The "signatures" were then interpreted to determine the underwater features. For example, from the air a patch of seagrass appears as a dark signature, however, other features, such as large mats of drift algae, live hard bottom, or oyster reefs, have similar-looking signatures. Scientists then conduct field visits to ground-truth the photographs. They identify the appropriate submerged habitat and make any corrections to the seagrass photograph legends.

Aerial photographs help researchers examine areas that may have undergone recent changes or have not been studied as extensively. They are also used to support other techniques, such as transect monitoring.

There were substantial seagrass losses, primarily in near-shore seagrass meadows in the NW quadrant seen in aerial photographs between 1996 and 1999, followed by an increase in shoal grass between 1999 and 2002. There were decreases along the transect from 2002 through 2004, and increases in abundance and cover through 2004. Between 2005 and 2006, there were substantial reductions in shoal grass coverage. Manatee grass was relatively stable during the most recent study period. Overall, there have been decreases in new seagrass, however, increases are seen when there are improvements in water quality.

Seagrass Transect Results

NW
- Decrease in shoal grass
- No change in manatee grass

NE
- Shift offshore from shoal and widgeon grass to turtle grass

SE
- Shift from turtle grass to turtle and shoal grass
- Increase in shoal grass

SW
- Shift inshore between shoal and widgeon grass
- Increase in offshore shoal grass

Transects show improvements in other quadrants

In the other three quadrants, seagrass coverage improved or was stable between 1996 and 2006. There were some shifts in seagrass species. In a small section of the NE quadrant, turtle grass began replacing shoal and widgeon grass. This indicates that the area may be entering a more stable period, as turtle grass does not colonize an area quickly, but tends to be more persistent. In the two south quadrants, there were increases in shoal grass.

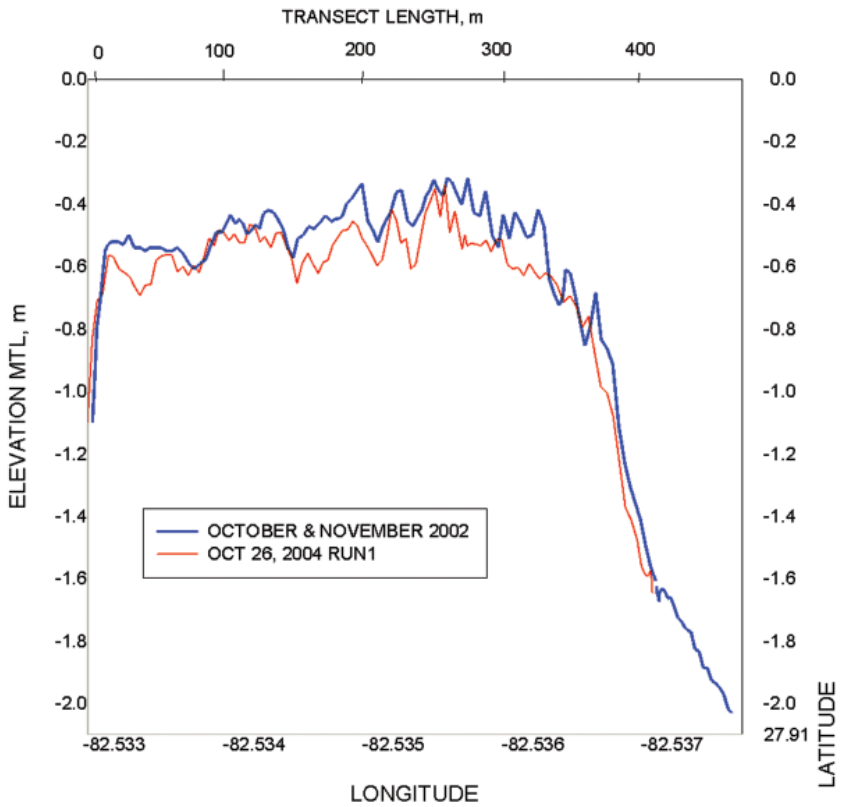
Bottom Line: Feather Sound seagrass coverage continues to decline.

Sediment erosion can lead to seagrass losses

Sediment elevation measurements can indicate erosion

Seagrass helps to hold sediment in place. When seagrass coverage decreases, it is common to lose sediment in the area, resulting in a decreased elevation. Conversely, natural occurrences, such as hurricanes, can cause losses of sediment that may lead to seagrass decreases.

Scientists can measure the elevation with precise GPS instruments. Results are then graphed using computer software to show the overall elevation of an area. If an area has been sampled several times, the results can be graphed together to show if an area has gained or lost elevation.



Elevation in the southeast quadrant from two time periods. Elevation decreased in 2004 (shown in red) from the 2002 (blue) elevations. Sediment elevation contours were taken from the near shore area to about six feet of depth at the transects and at 13 additional sites in the northwest quadrant. (These sample locations are shown on the aerial photograph on page 21). *(COTBSG)*

Scientist taking elevation measurements. (COTBSG)

Elevation results differed by quadrant

There was not a significant loss or accumulation of sediment in the NW or SW transects. Changes in sediment elevation, therefore, are not likely causes of slowed seagrass recovery in the Feather Sound region.

There were substantial losses in the offshore area of the NE and SE transects, with an associated loss of seagrass in the SE quadrant. The changes in elevation may have been from storm impacts during the 2004 hurricane season.

Bottom Line: Elevation has not significantly changed in Feather Sound. This suggests that changes in sediment elevation are not likely responsible for seagrass declines in the Feather Sound region.

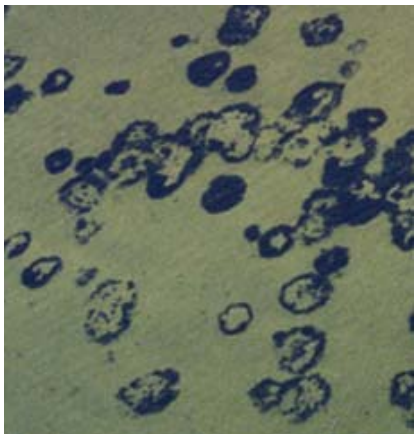
New seagrass patches may respond differently

Seagrass "donuts" appeared in Feather Sound in first study

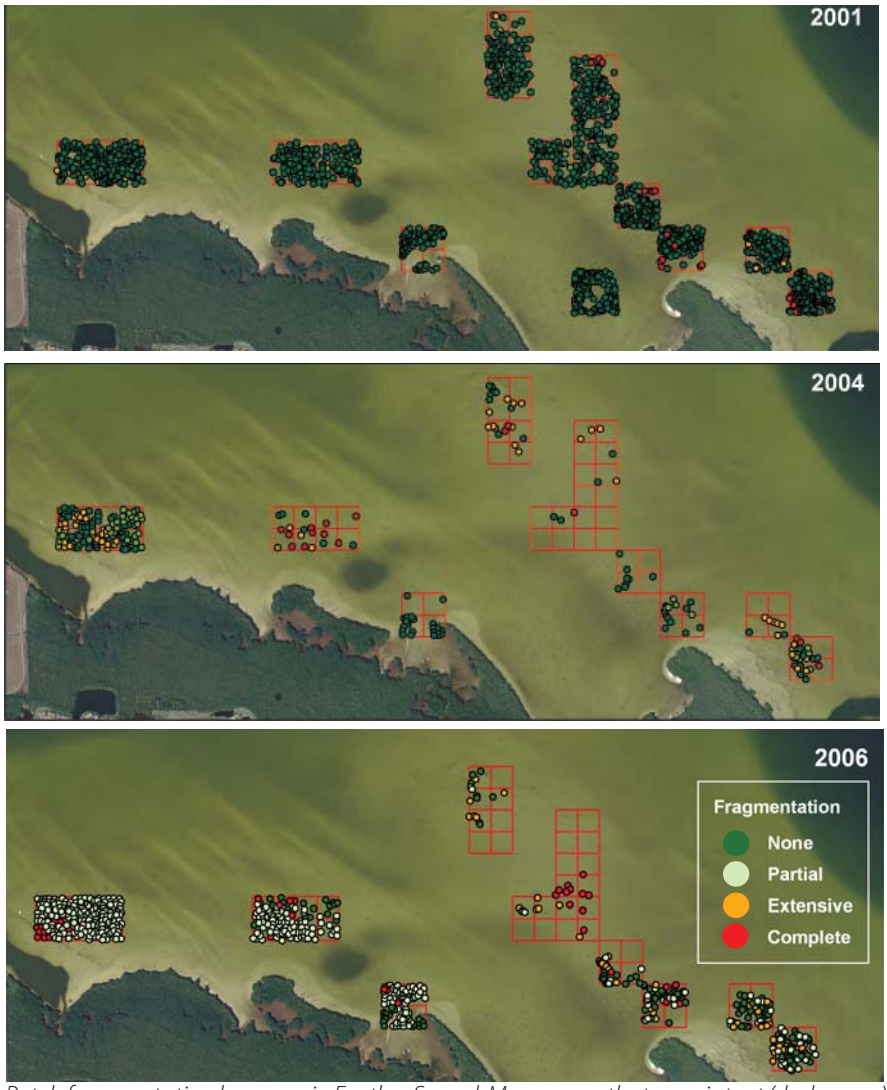
Volunteer patches of shoal grass that appeared in fall 2001 and spring 2002 began to die rapidly in late summer and fall 2002. Rather than disappearing completely, seagrass in the center of the patches began dying off first. In some patch groups, the fragmentation occurred in less than a month. This caused an unusual formation that looked similar to a donut and seemed to occur more often with the new patches of shoal grass than in areas with more persistent seagrass beds. Since the goal of the study is to increase seagrass coverage in Old Tampa Bay, learning the reasons why new patches fragments is very important.

In the Feather Sound region, patches responded differently depending on where they were located. Scientists grouped patches based on their location and tracked their progress as units. They noticed that patch groups exhibited similar patterns of growth or decline, which often were different than the neighboring patch groups. This might be due to slight differences in elevation.

During this study, scientists developed a series of experiments, discussed on the following pages, to learn more about reasons for patch failure and the causes of the strange "donut" formations in the hopes of preventing similar seagrass loss in the future.



Seagrass "donuts" in Feather Sound area. (Gandy Photography, Inc.)



Patch fragmentation by group in Feather Sound. Many areas that were intact (dark green) in 2001 were completely lost by 2004. New patches appearing in 2006 exhibited some degree of fragmentation. (FWC, FWRI)

Bottom Line: Volunteer seagrass patches in Feather Sound continue to show fragmentation.

Scientists test for causes of seagrass "donuts"

Scientists have suggested several possible causes of seagrass "donuts." They developed experiments in the field and the lab to test how seagrass beds would adapt to several factors that may be causing the "donut" formations. Results are continued on the following pages.

Possible causes of shoal grass "donut" formations

- Clonal senescence: direction of growing tips of seagrass roots. If all tips are growing outwards, seagrass in the center could die.
- Nutrient depletion: seagrasses require certain nutrients in the soil to grow. Nutrients in the center of patches may be used first, preventing grass in the center from growing.
- Hypoxia: low levels of oxygen.
- Sulfide toxicity: a high level of hydrogen sulfide that can be toxic to seagrass. This chemical is produced by bacteria in the soil.
- Bioturbators: organisms in the soil or water that can dig up seagrass rhizomes during grazing or burrowing.

Clonal Senescence

If all the seagrass rhizomes (roots) in a seagrass bed point outward, it may leave a bare patch in the middle with no growing tips to recolonize the area. Scientists tested this by collecting samples of seagrass and observing the growing patterns. Overall, more than 60% of the rhizomes with growing tips at the edge of the patch were oriented outward, while only 15% were pointed inward. Approximately 40% of rhizomes in center patches had no growing tips. Clonal senescence cannot be eliminated as a potential cause of fragmentation, however, because there were enough rhizomes with growing tips in the center to suggest they could recolonize bare areas.

Sediment Nutrients

Seagrasses require nutrients such as nitrogen (N) and phosphorous (P) to grow. Scientists analyzed seagrass samples for concentrations of these nutrients in seagrass blades, which can indicate availability of nutrients in the soil. Results showed that there were higher levels of N and P in the seagrass leaves in patches with less fragmentation. Concentrations of N and P were higher in the centers of healthier patches, but higher in the edges of patches with more fragmentation. Overall, the results did not provide enough information to determine if sediment nutrient concentrations are causing "donut" fragmentation.

Scientist showing a sample of a turtle grass with the rhizome. (Tampa Bay Watch)

Bottom Line: Sediment nutrient depletion and clonal senescence do not appear to be causes of seagrass "donuts" in Feather Sound.

Tarps over seagrass beds simulate algal mats

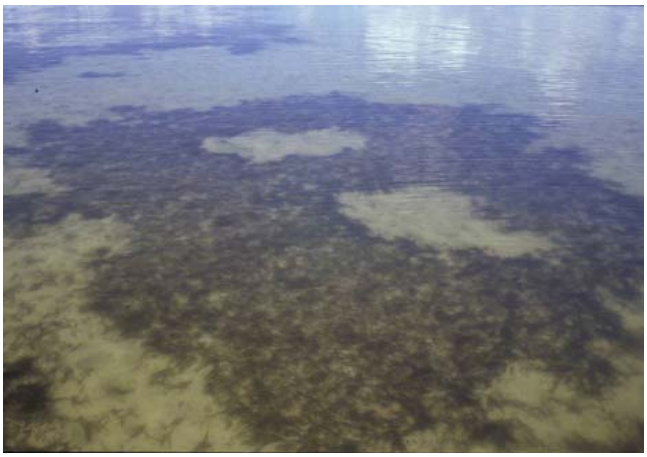
Low oxygen levels can impact seagrass

Seagrass rhizomes require an aerobic environment (containing oxygen) to maintain healthy growth. When the environment becomes hypoxic (low oxygen) or anoxic (no oxygen), especially combined with poor light availability, it can stress the plants by reducing their ability to photosynthesize, potentially causing death. The chemical hydrogen sulfide may also occur in greater quantities during low oxygen conditions, causing additional stress to the seagrass. Bacteria in the soil produce the chemical hydrogen sulfide when breaking down organic matter, such as decomposing seagrass.

Healthy seagrass can usually detoxify the sulfide, however, excess sulfide can cause a form of toxicity. Scientists hypothesize that sulfide can become toxic during the following instances:

- Hypoxic conditions may directly stimulate sediment bacteria to produce more sulfide, or
- Stress to the seagrass from less light and oxygen may cause death, which can stimulate sediment bacteria.

Scientists developed an experiment using large tarps to simulate drift algae over seagrass beds to test whether seagrass in the center experienced more stress than those at the edges when light availability was limited. The tarps were in place for one, two, or four days and scientists then measured the amount of sulfide in the sediment. There were higher concentrations of sulfide in covered areas after four days than in areas that were not covered with the tarp. There were no strong relationships, however, between sulfide concentration and the amount of seagrass cover, suggesting that short-term hypoxic events may not be causing patch formations. However, sulfide may still be a stressor for seagrass, especially when other conditions are suboptimal.



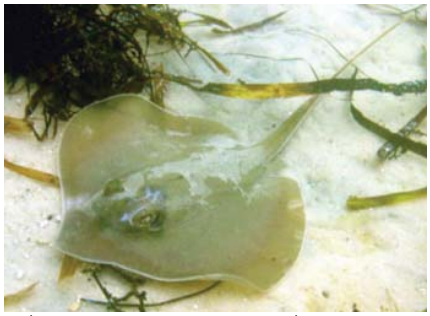
Tarp over seagrass (above left) to simulate mats of algae that can prevent light penetration into the water column, stressing the seagrass and limiting photosynthesis. The stakes were placed in the area to monitor seagrass within the experimental areas - those covered with opaque or clear tarps - and the control areas with no tarps. Scientists anticipated that tarps would cause areas of seagrass death, such as the "double donut" formation shown on the right; however, no seagrass death occurred during these hypoxia experiments. The causes of the "donut" formations are still unclear. *(FWC, FWRI)*

Bottom Line: No relationship was found between hydrogen sulfide concentrations and the amount of seagrass cover in short-term experiments.

Fences limit disturbance by large bioturbators

Baskets can keep out large bioturbators

Certain organisms, such as rays, horseshoe crabs, worms and shrimp, can disturb plants by burrowing in the sediments, much like moles in a terrestrial yard. Scientists hypothesized that both large and small bioturbators may impede seagrass growth and may even cause the "donut" fragmentation.



Atlantic stingray among turtle grass. (FWC, FWRI)

Scientists first transplanted seagrass into "baskets" with sediment from which all of the small burrowing organisms were removed. Seagrasses in baskets and at a control site at which organisms were not removed were monitored for a year. All of the transplanted seagrass in the baskets survived, along with seagrass at the control site. This suggests that small burrowing organisms did not affect the success of the transplanted seagrass.

During the experiment, large mats of drift algae began accumulating at one of the sites. To help keep the algae from smothering the seagrass transplants, scientists created fences made from chicken wire around the transplants. Within the fenced areas, seagrass transplants grew better and the coverage was denser than in areas without fences. While this was not the original intent of the experiment, it appeared that the mesh fences may have reduced the disturbance by larger bioturbators such as rays, resulting in enhanced seagrass growth. Fisheries monitoring data also suggests that stingray densities may be higher in Feather Sound than in the other three Old Tampa Bay quadrants and among the highest in Tampa Bay.

Pit created by a stingray among shoal grass patches. (FWC, FWRI)

While the pattern of fragmentation is too regular to be caused by large bioturbators, it is likely that animals such as stingrays and horseshoe crabs can still impact seagrass beds. Scientists suggest testing the use of fenced enclosures to protect newly transplanted seagrass areas from large bioturbators. This may serve as a useful management tool for improving success of seagrass transplanting.

Mesh fence used to keep algae from accumulating in study area kept large bioturbators out of seagrass beds. (FWC, FWRI)

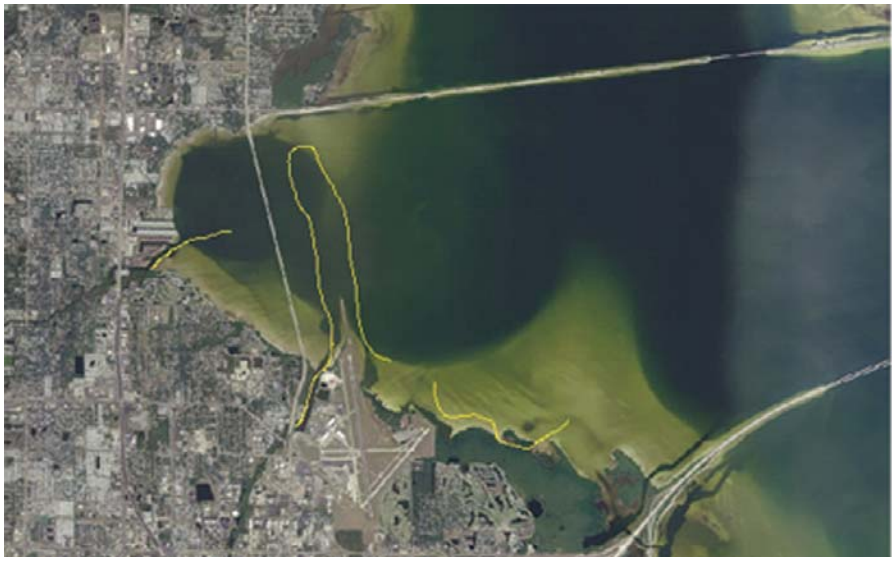
Bottom Line: Overall, there were no clear reasons for why seagrass "donut" formations occur. Enclosing seagrass in fences may be used in future transplant experiments to keep out large bioturbators.

New techniques detect anthropogenic pollution

Two innovative methods were tested to detect the sources of nitrogen-containing pollution from wastewater treatment plants and septic systems. The first involved testing for optical brighteners, which are chemicals used in laundry detergents to make clothes bright white. These compounds can be detected with an instrument called a fluorometer. When found, these brighteners may indicate presence of human waste from treatment plants or septic systems. The second experiment, described on the following page, involved testing algae species for ratios of stable isotopes.

Both techniques were initially tested to evaluate their effectiveness and to determine if they were appropriate for detecting manmade sources of pollution in the estuarine waters of Old Tampa Bay.

Many commercial laundry detergents contain brightening compounds that make laundry appear brighter and whiter (above photos). These compounds can be detected in waterbodies that receive discharge from wastewater treatment plants and/or septic systems.



Sampling in the northwestern portion of Old Tampa Bay focused on areas near the Clearwater wastewater treatment plant (top of path) and at the downstream section of Allen's Creek. The yellow line shows the path where fluorometers collected information about optical brighteners. (FDEP)

Optical brighteners not readily detected in the estuarine waters

Scientists used a fluorometer in the northwestern portion of Old Tampa Bay, close to a wastewater treatment plant discharge and small creeks that may contain run-off from septic systems, to detect optical brighteners in the water.

Results showed that there were very few signs of increases in fluorescence from brightening agents. Scientists concluded that the technique may not be appropriate for mapping wastewater discharges in larger, open-water areas. When this technique was used in other estuaries, it was limited to smaller areas, such as rivers. Due to the inconclusive results, this technique was not continued later in the project. However, scientists will continue refining this method and may use it in other areas around Tampa Bay, such as the freshwater rivers.

Bottom Line: Optical brightener test not appropriate for Old Tampa Bay.

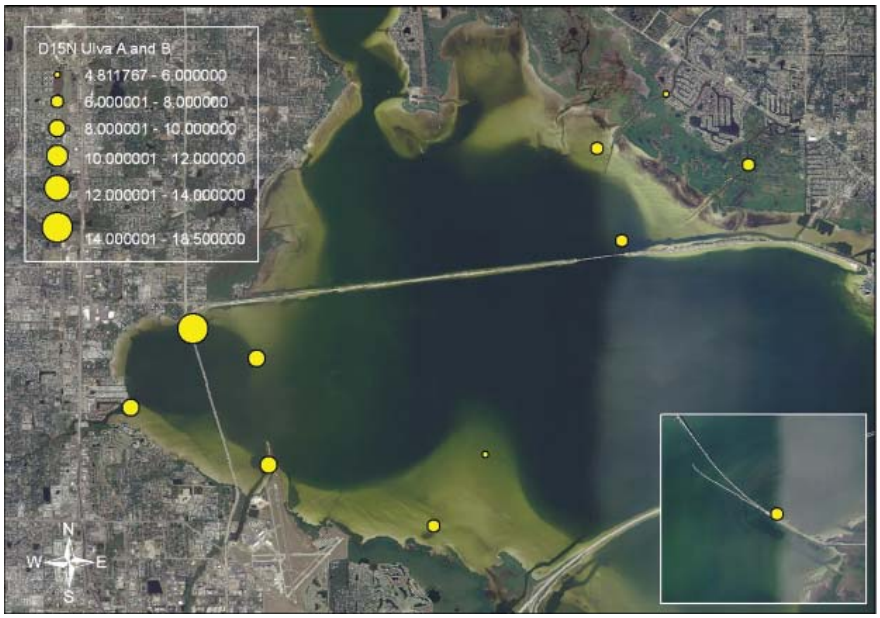
Algae indicate nitrogen sources

Chemical elements, such as nitrogen, can exist in different isotopic forms based on their atomic mass: a combination of the number of protons, which remains constant for an element, and the number of neutrons, which can differ. Nitrogen, for example, contains seven protons. It usually exists as nitrogen-14 (^{14}N) when there are seven protons and seven neutrons. However, if it gains an extra neutron, it will exist as the less-common form nitrogen-15 (^{15}N). Scientists can use the ratio between ^{15}N and ^{14}N, noted as the Delta 15-N ($\delta^{15}N$) to learn about various pollutant sources. Nitrogen that comes from fertilizer, an inorganic source, has a $\delta^{15}N$ value close to zero. Nitrogen from organic animal and human waste has a $\delta^{15}N$ value greater than ten. Elevated values of $\delta^{15}N$ generally suggest possible human or animal waste sources.

Plant tissues contain information about the environments in which they live. Scientists used algae species to detect sources of nitrogen in bay water. Samples of two algae species were collected from a background location, placed in plastic bags, and brought to study locations within Old Tampa Bay. Samples were kept in the study areas for roughly 1-3 weeks and then collected for isotope analysis.

Results from two algae species and two deployments were similar. Overall, there were highest δ15N values near the Clearwater wastewater treatment plant and elevated values at the mouth of two freshwater creeks that receive runoff from residential areas. This suggests that nitrogen here is from organic sources, such as human or animal waste found in wastewater or from septic systems. The lowest values were found on the Feather Sound hump, suggesting that nitrogen in this area may contain inorganic nitrogen sources, such as fertilizer, in addition to organic sources.

Algae samples were placed in plastic bags and attached to buoys. (FDEP)



Results of the stable nitrogen isotope algal sentinel, Ulva species, *averaged for the two sampling times. The larger dots indicate a higher $\delta^{15}N$ value, suggesting that the nitrogen is from organic sources, such as animal or human waste. The largest value is from the Clearwater wastewater treatment plant, with other positive $\delta^{15}N$ values near the mouth of two residential creeks on the western side of Old Tampa Bay. The small dot on the Feather Sound hump suggests that nitrogen in this area may come from both organic and inorganic sources. Fertilizer from the nearby golf courses may be a source of inorganic nitrogen. The inset picture shows a low $\delta^{15}N$ value from the background location in lower Tampa Bay near the Sunshine Skyway Bridge. (FDEP)*

Bottom Line: Feather Sound receives nitrogen from various sources, both organic and inorganic.

Runoff washes pollutants into Feather Sound

Water quality sampling from the first Feather Sound project demonstrated that water quality in this quadrant of Old Tampa Bay was poorer than in the other three quadrants. During this project, scientists measured stormwater runoff from the nearby Roosevelt watershed that drains directly into western Old Tampa Bay. This basin encompasses more than 8,000 acres and activities occurring on land can affect the water quality in the bay. Samples were taken at five locations in the watershed that drain to Old Tampa Bay through a series of ditches and mosquito-ditched mangrove systems. Water quality parameters included nitrogen and phosphorous (nutrients that, in excess, can lead to poor water quality), and total suspended solids and turbidity, which are measures of water clarity.

Scientists also placed instruments in the bay to measure the effects of rain storms on water quality, specifically whether the water became fresher as a result of increases in stormwater runoff.

Sampling locations are shown as red dots and the drainage basins are indicated by yellow lines. Sampling included the drainage of reclaimed water and stormwater from the Feather Sound golf course. (PCDEM)

Roosevelt Basin Stormwater Site 23-6:

- Stormwater runoff from 254 acres.
- ~1.6 miles from Old Tampa Bay.

Roosevelt Basin Site 23-7:

- Stormwater runoff from 1,115 acres.
- ~1.3 miles from Old Tampa Bay.

Salinity Barrier Stormwater Site 23-8:

- Stormwater runoff from 1,681 acres.
- ~1,300 feet from Old Tampa Bay.

Golf Course Site 23-21:

- Reclaimed water: ~ 0.4 billion gallons (in 2005).
- Stormwater runoff from 45 acres of golf course.
- ~2,600 feet from Old Tampa Bay.

Golf Course Site 23-22:

- Reclaimed water: ~ 0.8 billion gallons (in 2005).
- Stormwater runoff from 154 acres of golf course.

Salinity affected by stormwater runoff

Salinity meters were placed offshore in Feather Sound to detect effects of freshwater stormwater runoff. Because stormwater is a source of freshwater to estuaries, large volumes of runoff may decrease the salinity of receiving waters. A change in salinity of the bay, from high volumes of runoff, also suggests that stormwater pollutant loading may increase. Most storm events measured during the study produced only small, short-term decreases in salinity during low tide. Extreme rain events produced greater decreases that persisted up to two weeks.

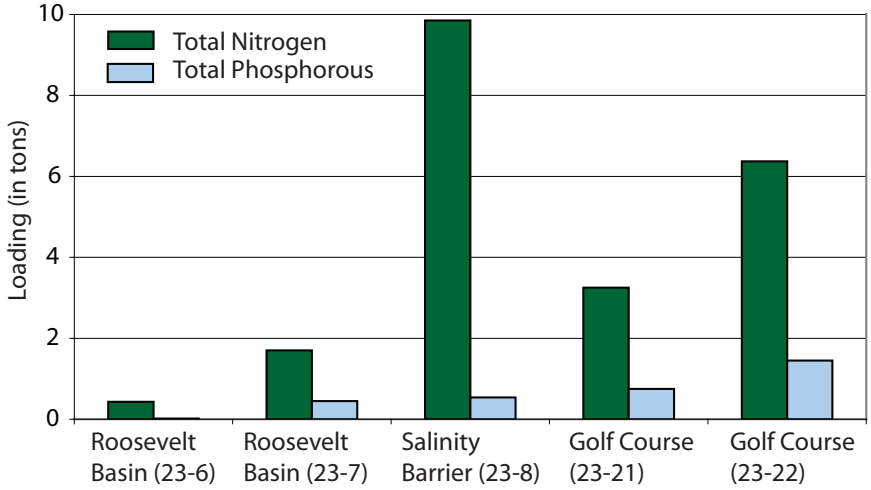
Sampling detects nutrient loading

Golf course sites contributed nitrogen to Feather Sound

Water sampled at the combined golf course sites contributed nearly as much total nitrogen loading to Old Tampa Bay (9.62 tons TN annually) and more than four times the loading of total phosphorous (2.2 tons TP annually) as the stormwater Salinity Barrier Site 23-8, which drains primarily residential areas. The high levels of phosphorous are likely from fertilizer used at the golf course.

Local scientists were already aware of the loading from the stormwater site at the Salinity Barrier (23-8) since it drains a large portion of the watershed. However, this was the first time that sampling occurred at the golf course, revealing a significant source of nutrients to Old Tampa Bay. Although the Roosevelt Basin is not the largest source of nitrogen to Old Tampa Bay, it contributes a significant amount based on its size. This suggests that improvements to the quality of runoff that drains to Feather Sound through the golf courses may improve water quality in Old Tampa Bay.

Estimated Annual Loading of Nitrogen and Phosphorous to Feather Sound from 5 Sites in Roosevelt Basin Watershed



Estimated annual loadings of total nitrogen (green) and total phosphorous (blue) during 2005 from five sampling locations. Loading includes base (dry weather) flow and flow from large rain events. Estimates for loading at the golf course come from the City of Largo treatment plant. Sites 23-6 and 23-7 contribute very little nutrient loading to Old Tampa Bay. The salinity barrier and combined loading from the golf course are significant nutrient sources to Feather Sound and may be impacting bay water quality. (PCDEM)

Plume of colored water from mangrove system entering Feather Sound. This may impact nearshore seagrass beds, although more research is needed to determine the importance of color in Feather Sound. (COTBSG)

Colored water can limit light for seagrass

Scientists did not measure color of stormwater at sampling locations, although this can limit light availability for seagrass. The concentration of chlorophyll *a*, which increases with excessive algal growth, may be the most important light-limiting factor for seagrass in this area; however, dissolved organic material in the water column from decomposing plant matter can also reduce available light. This surge of colored freshwater may occur after heavy rain events.

Bottom Line: There was significant nitrogen loading to Feather Sound from the golf course sites and a residential stormwater site.

Improved land management may benefit the bay

Scientists believe there are many impacts to the Feather Sound region and that seagrass in this area may be vulnerable to small degradations in water quality. In periods with less rainfall, water quality in Feather Sound is better and seagrass appears to recolonize the area. However, when there are years with heavy rainfall and a large amount of stormwater entering the bay, water quality can decrease enough to stress existing seagrass and/or prevent new seagrass from recolonizing. It will be necessary to address numerous impacts to the area and use a broad-based, multi-pronged approach for improving water quality. Stormwater and land management plans are being developed in some watersheds, such as the Roosevelt Basin, that will reduce pollutant loading into western Old Tampa Bay.

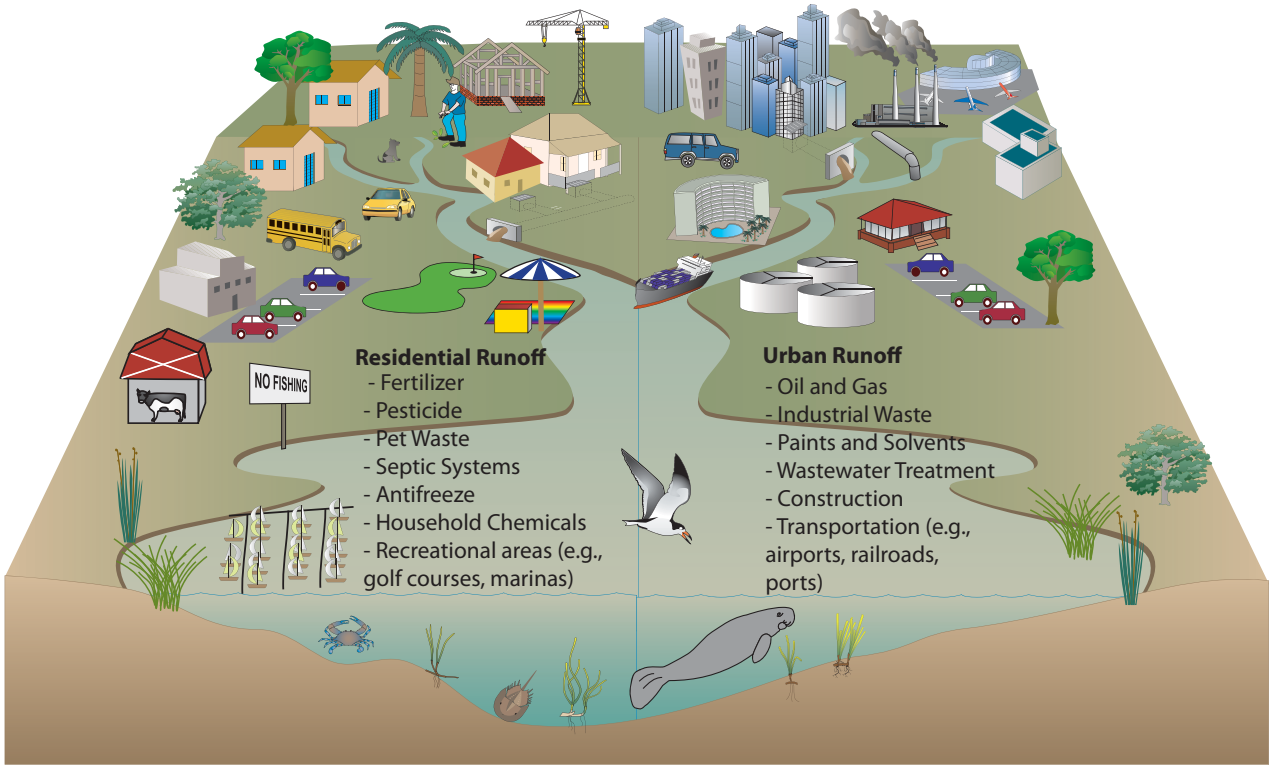
The conceptual diagram below demonstrates land-based activities that can impact water quality, along with suggestions for better managing runoff.

Residential Runoff Improvements

- Limit fertilizer and pesticide use
- Clean up and properly dispose of pet waste
- Recycle motor oil and automotive fluids
- Properly dispose of household chemicals
- Maintain septic systems to prevent leaking
- Improve golf course management

Urban Runoff Improvements

- Improve treatment of wastewater
- Increase use of reclaimed water for irrigation
- Fix aging stormwater systems
- Replace septic systems with sanitary sewer
- Reduce impervious surfaces (e.g., asphalt)



Bottom Line: Reducing pollutant loading to Tampa Bay is possible through combined efforts of residents, businesses, and governments.

Golf courses may impact environmental quality

Golfing is a recreational activity that is enjoyed by many Florida residents and visitors. Throughout the Tampa Bay region, there are more than 80 courses. Activities at golf courses can have both positive and negative impacts on environmental quality, depending on how they are managed.

Courses that use excess fertilizers and pesticides can cause nutrient pollution in receiving waterbodies and over watering turf grass with potable water can limit freshwater available for other uses or environmental protection. But golf course managers can also be stewards of the environment if appropriate management actions are implemented.

Improvements at golf courses may enhance environmental quality

Audubon International, a non-profit organization (not affiliated with the National Audubon Society), offers the "Certified Audubon Cooperative Sanctuary" program for courses that design and implement strategies to protect the environment and preserve natural and wildlife habitat areas. As of 2006, there were five courses in Tampa Bay that had Audubon Cooperative Sanctuary Programs. The Chi Chi Rodriguez Golf Course in Clearwater, Florida recently completed the certification program and has committed to promoting environmental quality for people and wildlife on the course.

Certified Audubon Cooperative Sanctuary golf courses document how they will meet environmental management standards in six key areas:

- Environmental planning,
- Chemical use reduction and safety,
- Outreach and education,
- Water conservation,
- Wildlife and habitat management, and
- Water quality management.

Pinellas County is contacting managers of the Feather Sound course and the community-run Airco course, near the St. Petersburg/Clearwater Airport, about participation in the Audubon International program.

The above photos from the Chi Chi Rodriguez golf course in Clearwater, Florida demonstrate environmental management standards in the "Audubon Cooperative Sanctuary Program" for which it has received certification. The photos on the left and right demonstrate the integration of wildlife habitat areas within the course. Freshwater wetlands and uplands areas attract birds and other wildlife. In the center photo, native plants are used near the putting green and are irrigated using reclaimed water. (PCDEM)

Bottom Line: Better environmental management at golf courses can benefit water quality and help to preserve wildlife habitat areas.

Mangrove systems have been severely altered

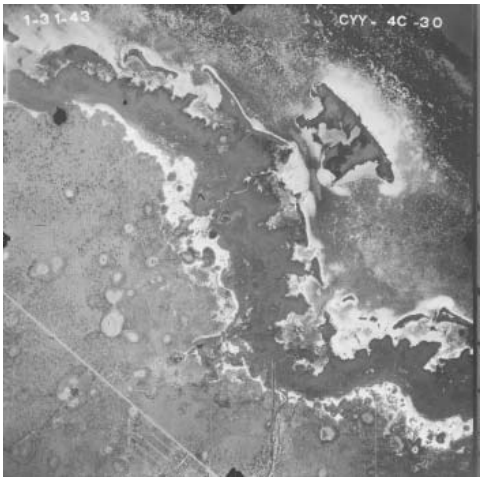
Pinellas County is the most densely populated county in Florida and the watershed that drains to Feather Sound is no exception. Since the early 1900s there have been significant changes to the land area, including increased development for residential and urban uses, construction of the Howard Frankland Bridge causeway, and alteration of low-lying areas for mosquito control.

During the mid-1900s, municipalities dug ditches through low-lying areas that drain to Tampa Bay, such as mangrove forests, in order to drain the standing water that mosquitoes need to hatch their eggs. These ditches were effective at reducing mosquito populations, but resulted in unintended environmental consequences. Sediment that was dug up to make the ditches was often piled along the side of the canals in small mounds. This created areas with slightly higher elevation and less contact with the brackish bay water. These areas became attractive to plants that previously could not live in the areas, including some non-native, invasive plants like the Brazilian pepper.

The ditches also altered the natural hydrology (the way that water flows) of the system, causing water to drain faster into receiving water bodies. Since mangroves utilize nutrients in water, this reduced the opportunity for the mangrove systems to treat polluted water before it enters the bay.

Aerial photos show extensive changes

The above photo shows extensive mosquito ditching in the Feather Sound area circa 1967. Photos below show the same area of Feather Sound near Big Island from two time periods. The bottom left photo is from 1943 prior to construction of the Howard Frankland Bridge causeway. The land area was most likely used as pasture land and did not have any alterations of the mangrove areas. The small dark dots near Big Island are patches of seagrass. The bottom right photo is the same area in 2002. Construction of the upland causeway required dredging of bay bottom, resulting in deeper areas alongside the causeway. Former agricultural land has been converted to residential areas, including the Feather Sound golf course. There are also fewer patches of seagrass visible near Big Island and the "hump." (USGS, Florida Aerial Photography)



Bottom Line: Mosquito ditches have changed the natural hydrology in mangrove systems and allowed non-native plant species to flourish.

Restoring mangroves may treat stormwater

The Feather Sound Golf Course receives reclaimed water from the City of Largo wastewater treatment plant to supplement irrigation, rather than using potable drinking water. Utilizing reclaimed water on residential lawns and recreational areas is an excellent way to reduce the demand for potable water. In Pinellas County, golf courses were one of the first private industries to utilize this water source for irrigation, which provides a benefit both to the environment and the users. The golf course, however, receives a large amount of reclaimed water - about 1.2 billion gallons in 2005. Although the water meets standards for nitrogen concentration, because of the high flow volume, there is a large total nitrogen load going to the bay.

The project team recommends using natural areas, such as marshes and mangroves to further treat reclaimed water before it enters Old Tampa Bay. This could be done by restoring existing fringing mangrove areas that serve as a buffer between the developed land and the estuary.

The left photo shows a mosquito-ditched canal. On the right is an example of a restored mangrove and salt marsh system that includes curved tidal creeks and a more natural hydrology. *(USGS, SWFWMD)*

Restoring mangrove areas may help treat water draining to the bay

Land managers often take altered areas and restore the type of habitat that previously existed, especially after significant development has occurred. They can do this by planting native plants and restoring the natural hydrology, for example. At Feather Sound, scientists recommend restoring the mangrove systems as a way to treat stormwater from the watershed and reclaimed water from the golf courses that drain into Old Tampa Bay. Land managers could fill in old mosquito ditches, re-grade the area, and encourage water to drain more slowly through the mangrove systems. These areas are often used to "polish" stormwater, allowing water to drain through more slowly and natural treatment to occur. Restoring the natural hydrology would allow the mangroves to utilize the nitrogen and phosphorous in the water, along with helping to reduce the concentration of other pollutants through absorption into the mangrove roots.

Bottom Line: Natural treatment of stormwater using mangrove systems may improve water quality in receiving waterbodies.

Several projects planned for Lake Tarpon

Pinellas County is implementing several watershed-based projects around Lake Tarpon, that drains into northern Old Tampa Bay, to reduce nutrient loading and improve water clarity. Lake Tarpon originally drained northward to Spring Bayou through an underground sink, which was closed off in 1969. A canal was dug in 1967 to drain excess water south from Lake Tarpon into northern Old Tampa Bay to prevent flooding of residential areas. It is currently the largest source of nitrogen to Old Tampa Bay and contributes more than 100 tons of total nitrogen annually.

The county will use aluminum sulfate (alum) injection systems at three stormwater systems - Areas 6, 23, and 63. Alum binds with phosphorous, suspended solids, and heavy metals, and causes them to be deposited into the sediments in a benign state. The solid material can then be removed as part of regular maintenance. The projects are designed to reduce nutrient and suspended solids loadings to Lake Tarpon up to 40% for nitrogen, 90% for phosphorus, and 95% for total suspended solids. Since the waters of Lake Tarpon enter Old Tampa Bay directly through the Lake Tarpon Outfall Canal, these improvements may also lead to better water quality in the Feather Sound region.

Lake Tarpon is the dark kidney-shaped lake at the top of the photo. A canal now connects the southern portion of Lake Tarpon to the northern portion of Safety Harbor, Old Tampa Bay. Feather Sound is located in the lower right corner of the photo. Water quality improvements at Lake Tarpon may benefit portions of Old Tampa Bay. (USGS) [Photos below (PCDEM)]

Area 6

- Northwest side of Lake Tarpon.
- Stormwater from 100 acres.
- US-19, residential, and commercial runoff.

Area 23

- Southwest side of Lake Tarpon.
- Stormwater from 212 acres.
- Primarily residential runoff.

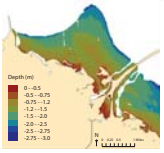
Area 63

- Northeast side of Lake Tarpon.
- Stormwater from 570 acres.
- Primarily residential and golf course runoff.

Bottom Line: Stormwater projects scheduled to be constructed by 2009 around Lake Tarpon may benefit downstream sections of Old Tampa Bay.

Additional research needs for Feather Sound

At the culmination of the first Feather Sound project the research team recommended additional research and monitoring for the region that, with support from the Pinellas County Environmental Fund, became the Feather Sound 2 project. Although the intensive study of this area has been completed, the project team has made additional recommendations that may aid in the recovery of seagrass in Feather Sound. The project team, with help from the scientific review committee, recommends the following future research priorities:

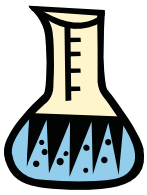


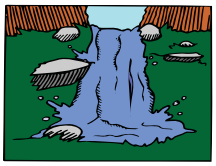
• Establishing more detailed and accurate bathymetric maps in regions of potential seagrass habitat. This may be especially useful for future application of the seagrass prediction model.

• Developing accurate assessments of diffuse and non-point source loads. During the current project, scientists identified the Feather Sound golf course as a significant source of nutrient loading to Feather Sound. It is important to monitor additional locations in the watershed to determine where nutrient loading is greatest and how the areas can be better managed.

• Determining minimum light requirements for Feather Sound seagrasses (likely to be greater than those at less degraded locations). If the seagrasses in Feather Sound are experiencing stress from other causes, such as bioturbation or variable residence time, they may require more light to become established and/or survive than in other areas of Tampa Bay.

• Shallow water monitoring of key water quality parameters, such as chlorophyll *a* and light attenuation. It is necessary for scientists to understand the estuarine environment in which seagrasses live. Additional water quality data from areas with seagrass habitat may improve understanding of requirements for healthy seagrass.





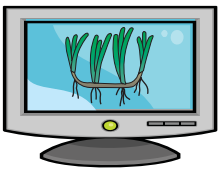
• Developing continuous monitoring capabilities to capture pulsed runoff from the mangrove systems into western Old Tampa Bay. Large quantities of runoff may increase the concentration of nutrients and other pollution in receiving waterbodies and may also decrease the salinity. Because aquatic plants, such as seagrass, have requirements for salinity and water clarity, these episodic events may stress the plants and lead to decreases in acreage. Once scientists understand the factors involved with increased runoff, it may be possible to manage the runoff more effectively. Suggestions include restoration of natural areas, such as mangroves, to slow and treat the water on its way to the bay.

Bottom Line: The Feather Sound projects have aided understanding of seagrass recovery in this area and identified priority restoration action. Additional research may improve management of seagrass in Tampa Bay.

Technical reports included on attached CD

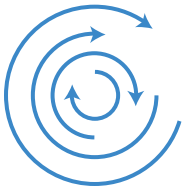
This document provided summary information about the project tasks and management recommendations for the recovery of seagrass in Feather Sound, Old Tampa Bay, Florida. Additional information, including raw data and more technical analyses, are available on the attached CD. The technical reports are listed by title, authors, and affiliations.

Factors Affecting Seagrass Recovery in Feather Sound, Old Tampa Bay: Field Operations Manual: Standard Operating Procedures and Quality Assurance Project Plan: Version 2.2
Lindsay Cross and Alice Ketron (*Tampa Bay Estuary Program*)



Pinellas County Environmental Fund Tasks B-1 and B-2 Technical Report: A Method to Predict the Occurrence and Distribution of Seagrasses in Old Tampa Bay Using Ambient Water Quality Data
Ray Pribble, Anthony Janicki (*Janicki Environmental, Inc.*); and David Wade (*Glaxo SmithKline, Plc.*)

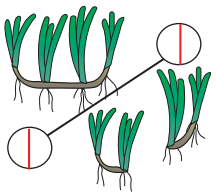
Task H- Collection of Field Data to Validate Old Tampa Bay Optical Model Predictions
Jennifer Kunzelman, Penny Hall, Donna Berns, Manuel Merello, Genoa Griffin, and Katie Toth (*Florida Fish and Wildlife Conservation Commission, Florida Fish and Wildlife Research Institute*)



Pinellas County Environmental Fund Task G Technical Report: Examination of Circulation Effects on Water Quality in Tampa Bay
Ray Pribble, Anthony Janicki (*Janicki Environmental, Inc.*); Steven Meyers and Mark Luther (*University of South Florida, College of Marine Science*)

Re-engineering the Western Howard Frankland Bridge and its Impact on Residence Time: Preliminary Results (Power Point presentation)
Steven Meyers and Mark Luther (*University of South Florida, College of Marine Science*)

Technical reports included on attached CD



Seagrass Transect Monitoring and Aerial Photography in Old Tampa Bay: A Technical Element of the PCEF II Project (2004-2007): Implementation of the Tampa Bay Seagrass Restoration Strategy
Roger Johansson, Walt Avery, Kerry Hennenfent and John Pacowta (*Bay Study Group, Wastewater Department, City of Tampa*)

Final Report for Task C: Experimental Studies of Seagrass Bed Fragmentation
Paul Carlson, Laura Yarbro, Herman Arnold, Alice Ketron, and Stephanie Sunderman (*Florida Fish and Wildlife Conservation Commission, Florida Fish and Wildlife Research Institute*)

An Evaluation of Two Methods for Mapping the Spatial Extent of Effluent from Wastewater in Old Tampa Bay: Old Tampa Bay PCEF II Task E Final Report
Chris Anastasiou (*Florida Department of Environmental Protection*); Paul Carlson (*Florida Fish and Wildlife Conservation Commission, Florida Fish and Wildlife Research Institute*); David Hollander (*University of South Florida, College of Marine Science*); and Charles Kovach (*Florida Department of Environmental Protection*)

External Land Based Loadings to Feather Sound (Task F): A Technical Element of the PCEF Project
Mark Flock and Cynthia Meyer (*Pinellas County Department of Environmental Management*)

Peer Review of Feather Sound Seagrass Recovery Workshop, March 20th-21st, 2007 at the Florida Fish and Wildlife Research Institute hosted by Tampa Bay Estuary Program
William Dennison, (*University of Maryland Center for Environmental Science*); Charles Gallegos (*Smithsonian Environmental Research Center*); Robert Virnstein (*St. John's River Water Management District*); and Walter Boynton (*University of Maryland Center for Environmental Science*)

Feather Sound Seagrass Recovery Project

Final Report and Management Recommendations for Feather Sound, Old Tampa Bay, Florida

A report to the Pinellas County Environmental Fund

Pinellas County Environmental Fund

By the Feather Sound Seagrass Recovery Project Team

Tampa Bay Estuary Program

City of Tampa, Florida — Mascotte — Organized July 15, 1887

Florida Fish and Wildlife Conservation Commission

Southwest Florida Water Management District

Pinellas County

Janicki Environmental, Inc.

Department of Environmental Protection — Florida

USF — University of South Florida — College of Marine Science